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Concentration of fluorspar ores in the Illinois-Kentucky District

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Department:

CONCENTRATION OF FLUORSPAR ORES

IN THE

ILLINOIS-KENTUCKY DISTRICT.

- By -

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A

THESIS

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C O N T E N T S.

T A B L E S.

I L L U S T R A T I O N S.

PREFACE.

The object of this investigation is to study the means of beneficiating fluorspar ores in order that a marketable product may be made.

The results of the investigation embodied in this thesis were obtained at the Mississippi Valley Experiment Station of the United States Bureau of Mines, Department of Commerce, in cooperation with the Missouri School of Mines and Metallurgy, Rolla, Missouri during the period from February 1, 1927 to February 1, 1928.

ACKNOWLEDGMENTS.

The writer wishes to take this opportunity to show his appreciation and to thank the Franklin Fluorspar Company, Paducah, Kentucky for permission to do this work under a fellowship status at the Missouri School of Mines and Metallurgy.

Acknowledgments are due Mr. Will H. Coghill, Supervising Engineer of the Mississippi Valley Experiment Station of the United States Bureau of Mines, under whose supervision the work was done; to Messrs. H. M. Lawrence, Metallurgist, F. D. DeVaney, Assistant Metallurgist, H. D. Scruby, Assistant Metallurgist, R. G. O'Meara, Junior Metallurgist, and A. B. Campbell, Junior Metallurgist, all of the United States Bureau of Mines, with whom the author was associated during the course of the investigation.

INTRODUCTION.

The importance of fluorspar in the industrial development of the country, particularly in the open hearth steel and growing aluminum industries, has just begun to be fully realized. During the World War fluorspar was found to be an essential mineral, but it also was found to be one which was not as abundant in commercial grade as had been supposed. The strong demand for it lead to a very vigorous search for new deposits, but with little success.

General Description of Fluorspar.

Fluorspar is a moderately hard mineral, transparent or translucent, crystallizing in the isometric system, usually in the form of cubes. It commonly occurs in crystalline masses, frequently in well formed crystals, less often in granular form. Its color is variable, nearly all colors being known. The most common color found, especially in the larger deposits, is white or gray. Fluorspar consists theoretically of 51.1 per cent calcium (Ca) and 48.9 per cent fluorine (F). Fluorspar in quantity analyzing 99 per cent is rarely found. By far the largest proportion of material shipped contains only 85 per cent calcium fluoride. Most fluorspar as mined contains silica or calcite, or both, together with small amounts of iron and aluminum minerals. Other more or less commonly associated minerals are galena, sphalerite and barite.

Fluorspar has a hardness of 4, and a specific gravity of 3.18. The melting point ranges from 1270° to 1387° C. and is very fluid when melted.

Fluorspar Deposits.

Fluorspar is found in nearly all the countries of the world, but in many instances the deposits are small, of such low grade, or so far from transportation facilities that they cannot be mined economically at the present time. As the milling problems of low grade ore become better understood and transportation conditions improve, no doubt many of the non-productive fields of today will be the valuable fields of tomorrow.

The deposits upon which the market depends are found in the United States, Great Britain and Germany. Small production has been made intermittently from deposits found in France, Canada, Argentina, Spain, Mexico, South Africa, Australia, Italy, Switzerland, Bavaria, and Saxony. Fluorspar has been found in Cuba, India, China, Guatamala, Norway, Persia, Brazil, and Bolivia, but as yet the quality or quantity of these deposits has not been sufficient to justify commercial exploitation.

The different deposits vary in their general geologic formation. To give a general geologic description of all the fluorspar deposits or even a detailed geologic description of one deposit would not be in accord with the intent of this paper, but a few generalities will be taken up concerning the Illinois-Kentucky deposit, which is the principal source of fluorspar in the United States. This deposit is found in a rather small area which extends from Hardin and Pope Counties in Southern Illinois across the Ohio River into Crittenden and Livingston Counties in Western Kentucky.

Igneous and sedimentary rocks occur throughout this district. The igneous rocks are represented by a number of dikes found near the Ohio River; the sedimentary rocks represent four systems, namely, Devonian, Carboniferous, Tertiary, and Quaternary. The region has faults which vary from nearly horizontal to vertical. For the most part fluorspar is found in well defined crystalline masses along these faults, although there are a few exceptions where it is found in horizontal beds or in pockets. The association of minerals and the common phenomenon of marked silicification of the hanging walls is interpreted as indicating deposition by heated ascending solutions. Fluorite crystals are rarely found in druses, indicating that secondary enrichment was not a factor in this ore deposit.

Production of Fluorspar.

The earliest recorded use of fluorspar was by Agricola, who noted its use as a flux in 1529. In the primitive methods of some of the smelting processes fluorspar was considered an indispensable fluxing material. Improved methods and equipment enabled smelters to substitute lime for fluorspar except in the case of the more refractory ores. This practice continued until the latter part of the nineteenth century.

The earliest recorded output of fluorspar in the United States was in 1835, when a small amount was produced near the site of the Old Columbus Mine in Crittenden County, Kentucky. In 1837 a small production was made from a topaz vein near Trumbul,

Connecticut. The first record of production in the Illinois field was in 1842, when a small amount was produced as a by-product from lead and zinc mines. Apparently, however, fluorspar had little or no market value until about 1882, when 4,000 short tons were produced in the United States, valued at $20,000. Production and price varied throughout the succeeding years, reaching, in 1918, a maximum of 263,817 short tons valued at $5,465,481.

During the early days of fluorspar it was primarily mined as a by-product from lead and zinc mines. At that time small, unsystematic operations prevailed. The mines were worked by short-time leases which often included small sections of the vein—frequently only one hundred feet. No effort was made to thoroughly work out the vein. Only the best and most easily accessible grades of ore were removed before the contractors abandoned their leases and asked for new ones, thereby leaving no record of their workings. Subsequently the workings caved, and at present it is very difficult for the new producer to take up the work where the pioneer left off in order to bring the mine up to modern standards.

Uses of Fluorspar.

The records indicate that the earliest use of fluorspar in the United States was as a flux in smelting refractory ores. The most important early use of fluorspar from the point of tonnage consumed was in the manufacture of opalescent glass, enamels, and hydrofluoric acid. This situation continued until 1898 when the value of fluorspar as a flux and cleaning agent in the basic open

hearth steel process was first realized. The demand for fluorspar as a result of this new use has steadily increased, until in recent years 80 to 85 per cent of the world's production is used for this purpose.

The following table summarizes the distribution of fluorspar among the industries:

Table I: - Distribution of Fluorspar in the Industries.

Consumer	1921 Percent	1922 Percent	1923 Percent	1925 Percent	1926 Percent
Steel Industry	73.09	86.44	80.00	80.82	82.33
Glass and Enamel ware Industry	16.02	6.29	9.10	8.81	8.51
Hydrofluoric Acid and Aluminum Industries	5.24	3.38	5.57	3.91	2.61
Foundry	4.35	2.12	2.68	5.53	4.84
Miscellaneous	1.30	1.77	2.55	0.93	1.66

The chief purpose of fluorspar in the manufacture of steel is to render the slag more fluid. When the slag is sufficiently fluid the transfer of heat from the flame to the steel beneath the slag is hastened. Thus, the time and duration of the heating is reduced and the increased fluidity of the slag enables it to be drawn with less difficulty. In addition to these advantages, fluorspar serves other purposes by virtue of its chemical action, namely, its tendency to eliminate sulphur and phosphorous.

The average quantity used per ton of steel varies within wide limits, from as low as four pounds to as high as twenty pounds, usually averaging eight pounds per ton of steel.

The specifications for fluorspar as used in the steel industry call for a sized product ranging from a maximum of about 3|4-inch diameter down to a fine dust; however, the fine material must not exceed 25 per cent through 20 mesh. A minimum of 85 per cent fluorite and a maximum limit of 5 per cent silica is stipulated. This type of ore is known on the market as gravel spar. Fine mesh fluorspar can be used, but some of it is lost in the furnace draft, and for this reason is objectionable to the steel industry.

At present no economic substitute for fluorspar in the steel industry is known.

In foundry practice fluorspar is used for the same reasons that it is used in the steel industry. It is also believed by some to make the iron more malleable and to increase the tensile strength by slagging off impurities. By this practice cast iron is made softer without decreasing its wearing qualities. Its use allows sharper castings. The specifications of fluorspar for use in foundry practice are the same as for the manufacture of steel.

Fluorspar is used in smelting refractory ores of gold, silver, and copper and, to some extent, in both the smelting and refining of silver-lead ores. The purpose of its use and the specifications are the same as noted above.

In the manufacture of opaque or opal glass and enamel-ware fluorspar is used as a source of fluorine, which with the aluminum furnished by feldspar, kaolin, or lepidolite imparts an opalescent white color to the glass. This coloring is due to the colloidal suspension of very small particles of aluminum fluoride. The trade requires 80 to 100 mesh material with the following analysis:

CaF_2	95 to 98 per cent minimum
SiO_2	1 to 3 per cent maximum
Fe_2O_3	0.1 per cent maximum
Pb, Zn, and S	Trace maximum.

The amount of fluorspar used in the charge in the manufacture of opal glass is from 20 to 30 per cent. In the manufacture of enamel-ware from 5 to 7 per cent per batch is required.

Fluorspar is also used to make hydrofluoric acid, which in turn is used for the manufacture of fluorine compounds, such as artificial cryolite and sodium fluorite.

The aluminum industry uses cryolite in the extraction of aluminum metal from aluminum oxide (Al_2O_3). Sodium fluorite is used as a wood preservative, food preservative, and an antiseptic. When fluorspar is used in the manufacture of acid it is furnished in lump or ground form, with a minimum of 98 per cent fluorite and a maximum of one per cent silica. This material is known as acid spar.

In the past the higher grades of ore demanded by the market have been obtained at a great sacrifice of ore reserves, that is, only the high grade ore was used. If the ore was milled the best grade was hand-picked, while the gravel grade was made by crude log washing. After capital became interested, the industry adopted jigs and tables, but with the best methods of jigging and tabling a large percentage of fluorite is still being lost in the mill tailings. The industry is now interested in developing methods whereby a high grade concentrate may be made from a fair grade of mine run ore, that is, the manufacture of acid spar, which is the object of this research.

Requirements in the Milling of Fluorspar.

The requirements in the milling of fluorspar depend upon the nature of the ore and the demands of the industry.

The impurities or associated minerals may be roughly divided into:

(1) Those which have no harmful effect in the common methods of utilization, and which may be classed as only diluents.

(2) Impurities which are really injurious in the process for which fluorspar is used, and which must be entirely eliminated or reduced to a very small percentage.

The classification of the impurities depends upon the purpose for which the mineral is to be used.

While the so-called harmless impurities act merely as diluents, they are not tolerated in large quantities of merchantable fluorspar. Thus, ordinarily the lowest grade of fluorspar is the gravel grade which contains at least 80 per cent fluorite and not over 5 per cent silica. The remainder is generally calcium carbonate with small amounts of the harmful impurities. The problem of milling, therefore, resolves itself into the elimination of all injurious impurities present, thereby raising the grade of the ore to meet the specifications.

Figure 1 (Page 10) shows a flow sheet of one of the old-time mills. This flow sheet is followed, with some changes, to meet the advanced ideas and demands in mill construction.

The demand for a gravel ore and the comparatively easy method of obtaining this size by jigging and tabling has caused a tendency on the part of the producers to neglect the fine mesh material, although it contains a high percentage of fluorite. The recovery of this material has been primarily in the hands of the mechanical engineer. He has been quite successful when handling sulphide ore with a heavy mineral and light gangue, which will yield a concentrate by simple methods. However, when an ore in which the variation of specific gravities is small, as is the case with fluorspar ores, better ore dressing is required.

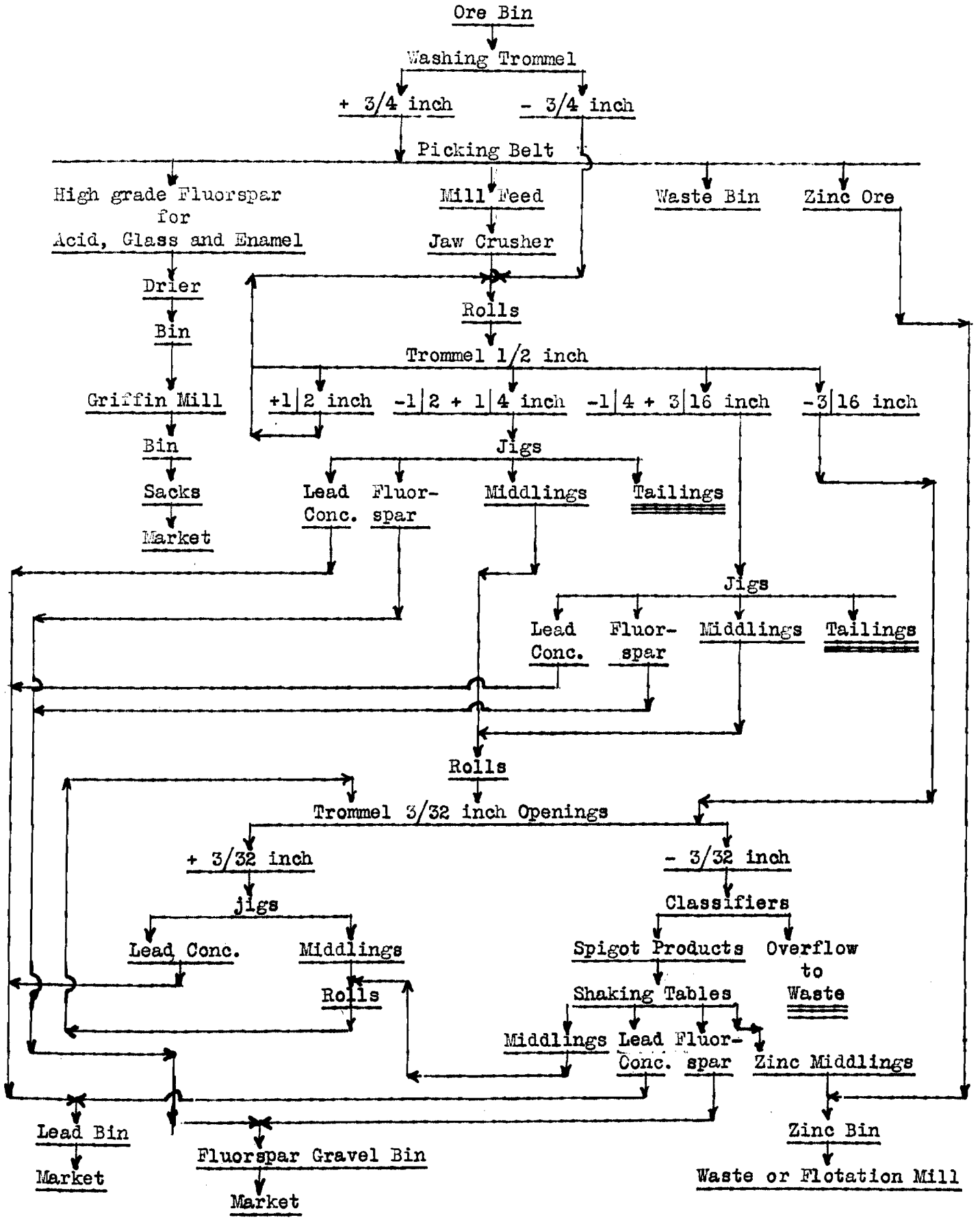

Figure 1. General Flow Sheet of a Fluorspar Mill.

The interdependence of the classifier and table may be easily passed unobserved when concentrating an ore in which the difference in specific gravity between mineral and gangue is as much as 4. When heavy mineral is locked with a gangue so that the ore contains chats of various densities the interdependence of the classifier and table must be taken into account if the locked minerals are to be recovered. The recovery of fluorspar is analogous to the locked mineral of the sulphide ores.

The Illinois-Kentucky ore in many cases is intimately mixed with gangue, which for the most part is composed of calcite, quartz and quartzite; in some cases lead and zinc occur in varying amounts.

Calcite and fluorite have nearly the same specific gravity and the ratio of their weights in water is not very favorable to water concentration. Gravity concentration, however, is more desirable than flotation when gravel spar is required.

Trommel or screen classification of the plus 2 mm. size has been made easily, but when handling minus 2 mm. size many difficulties were encountered and the attempt to handle this fine material was considered impractical by many producers until recently, when new interest has been taken in this phase of milling.

It is well known to metallurgists that successful tabling of fine material can only be obtained when a sized or classified feed is used, but the application of this principle to practice has been tardily applied. Screens and various methods of classifying have been tried but with unsatisfactory results, probably due to the ab-

sence of a thorough knowledge of the ore at hand and the proper application of the principles of classification.

The successful concentration of fluorspar depends as much upon its type and the physical properties of the mineral itself as upon the associated impurities. This problem of removing all the above-mentioned impurities and diluents is very acute in the fluorspar industry. The loss of fluorite in the tailings is quite high, especially in the finer sizes, and for this reason it was thought that a better knowledge of concentration could be obtained through a close study of the application of hydraulic classification principles to a fluorspar ore.

CLASSIFICATION.

The subject of classification will be taken up in the following manner:

(1) The reasons for classification and the different methods used.

(2) Laws and principles of classification.

(3) Experimental Investigation of classification.

Reasons for Classification.

The general principles of classification are largely taken from observations made by Richards.[1]

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[1]Richards, R. H., and Locke, Chas. E., A text book of ore dressing; 1925; second edition. McGraw-Hill Book Co., New York.

In order to concentrate and separate the valuable minerals in the crushed ore some sort of preliminary treatment is usually necessary. Many tests on the jerking table have proved the following:

(1) The results obtained with unprepared feed is completely outclassed and surpassed by sized or classified feeds.

(2) Classified feed is as advantageous as sized feed, and in case of much middle-weight mineral it is probably more advantageous.

If a natural or unprepared product is put on a table, a middling which contains large grains of concentrate, tailings which contain too much mineral, and a concentrate which contains too much gangue will always be made. Sized or classified feeds reduce these losses.

There are two methods of preparing table feeds. First, we may size it with screens; second, we may divide the ore into a series of products, in each of which the grains have approximately equal settling ratios, that is, perform hydraulic classification.

When sizing is employed the limiting sizes of the successive screens depend upon the nature of the ore. In a general way, the greater the difference of specific gravity between the mineral and the gangue the greater may be the ratio between the diameters of the openings in successive screens, that is, a less number of limiting screens will be required. The limit down to which screening can take place and beyond which hydraulic classification should be used must be decided for each individual ore.

Principles of Classification.

In studying the laws of classification by settling in water we have two conditions of the settling of grains to be recognized. They are called free-settling and hindered-settling.

Free-settling takes place where individual particles fall freely, either in still water or against an opposing upward current without being hindered by other particles.

Hindered-settling takes place where particles of mixed sizes, shapes, and gravities in a crowded mass—yet free to move among themselves—are sorted in a raising current of water. The velocity of this current is much less than the free falling velocity of the particles, but yet fast enough so that the particles are in motion.

The rate of falling for particles under free-settling conditions depends, other things being equal, upon:

(1) Specific gravity—of the two particles having different specific gravities, the one having the higher gravity will fall faster.

(2) Size—of two particles, the larger one will settle faster in the water.

The specific gravity and size have a further effect upon the rate of acceleration of the particles during the time they are acquiring their full velocity, that is, before they reach the point where the friction of the water, plus the force of the rising current, if there be any, balances the force of gravity. This effect is: That of two particles which are equal-settling, the smaller particle with

the higher specific gravity reaches its full velocity quicker than the larger particle with a lower specific gravity, or, in other words, it has greater acceleration.

(3) Shape—of particles which just pass through the same screen, the roundish grains settle faster than the long, narrow ones, and the latter settle faster than the flat grains.

(4) Air Bubbles—of two particles, one of which retains adhering air bubbles while the other does not, the latter will settle more rapidly. Water is sometimes so charged with air that bubbles form upon immersed grains and tend to float them.

Passing from free-settling to hindered-settling does not give a definite dividing line; upon one side grains are obeying the laws of free-settling and upon the other the laws of hindered-settling.

In order that hindered-settling conditions may be obtained a quicksand column must be maintained in which the grains are able to move up or down freely and at the same time the discharge must be free. To do this the velocity of the rising current must be enough to keep a definite volume of grains of a certain size in a state of full teeter.

The moment hindered-settling conditions are reached a new condition of affairs from those of free-settling must be taken into consideration. A larger part of the sorting column is occupied by sand and the actual velocity of the water current in the interstitial spaces is much greater than is indicated by the velocity of

the column. In other words, a rising current which is totally unable to lift a single grain of a given size is able to keep in full teeter a considerable mass of grains of the same size and weight.

The essential difference between a product classified under hindered-settling conditions and one classified under free-settling conditions is the higher ratio between the average diameters of the lighter and heavier particles in the case of hindered-settling. High ratios do not, however, mean hindered-settling or even good classification. It is possible by over-feeding a free-settling classifier to throw large grains of light mineral, which should go into the first spigot, into a latter spigot and thus obtain high ratios. It is evident that a product of this sort is not suited for efficient tabling. In the free-settling classifier there is a great tendency for fine particles of light material to be carried down mechanically into an earlier spigot than that in which they belong. This holds true to a considerable extent even in the most perfect classifiers and under the best conditions. In the case of the hindered-settling classifier, the fact that the grains are kept in a state of agitation in the quicksand column, constantly colliding with neighboring grains and teetering up and down, tends to break up such couples and allow each grain to take its proper position.

The ultimate aim of hydraulic classification is to divide the ore into graded products, each of which is made up of relatively coarse gangue and fine mineral.

Experimental Investigation of Classification.

A sample of mill tailings from the sludge pond of the Haffaw Mill, situated on the Tabb Vein, Mexico, Kentucky, was selected for study. Two reasons justified this selection.

(1) The largest loss of fluorspar is in the minus 10 mm. material; the sludge pond tailings consist primarily of this size.

(2) The tenor of this ore is: Silica - 17.93 per cent; Calcite - 1.88 per cent; and Fluorite - 80.19 per cent. The small size and high silica content outlaws this material from any market. If the fluorite can be raised to a 98 per cent minimum and the silica dropped to a one per cent maximum, a keynote has been sounded whereby a loss can be turned into a profit by all fluorspar companies.

Apparatus:

A small glass laboratory classifier was used for the preliminary study of classification principles and is shown in Figure 2. It consists of a glass tube 24 inches long and 3-3/4 inches in diameter. The holes in the constriction plate at the bottom of the glass tube are 1/16-inch in diameter, centers spaced 1/4 inch after the manner of equilateral triangles. The water for hydraulicking was forced through the constriction plate and discharged at the top.

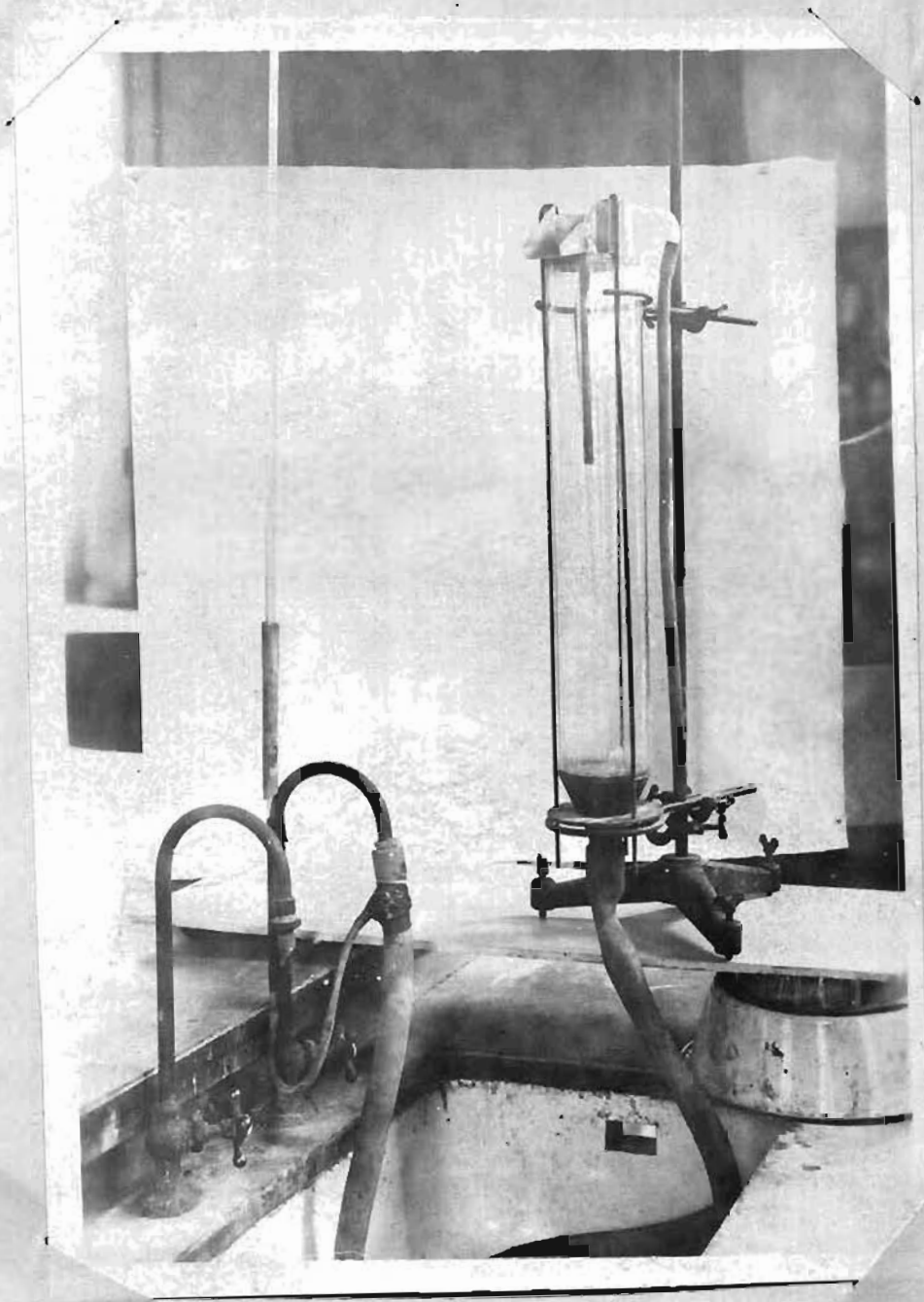


Figure 2. The Glass Laboratory Classifier.

A six-spigot laboratory size Richards hindered-settling classifier was used for large scale work and is shown in Figure 2-A.

For the concentration tests on the coarser material a quarter size Butchart table, Model 6, was used.

A quarter size Deister-Overstrom table was used for the finer sizes.

For making screen analyses of the products from the above-mentioned apparatus, the fourth root of two sieves—Tyler standard screen scale—were used.

The assays were made by the float-and-sink method. Acetylene tetrabromide was the separating medium. It was kept at a constant specific gravity of 2.95 to float the calcite and silica, and sink the fluorite. The calcite was then determined by difference after dissolving it out of the float with dilute hydrochloric acid. This method of assaying was adopted for several reasons. It is much more rapid than chemical analysis, and, for the study of classification, where the specific gravity of the grains is the most important feature, gives a more accurate interpretation of the efficiency of the classifier than does chemical analysis. The observed accuracy of the float-and-sink method will be mentioned later.

Content and Distribution of Fluorspar in Sample:

The sample from the Haffaw sludge pond contained some foreign matter and muddy slime. The coarse foreign matter was removed by scalping on a 10 mesh screen. The slime was removed by treating it on a concentrating table which was operated as a desliming machine.

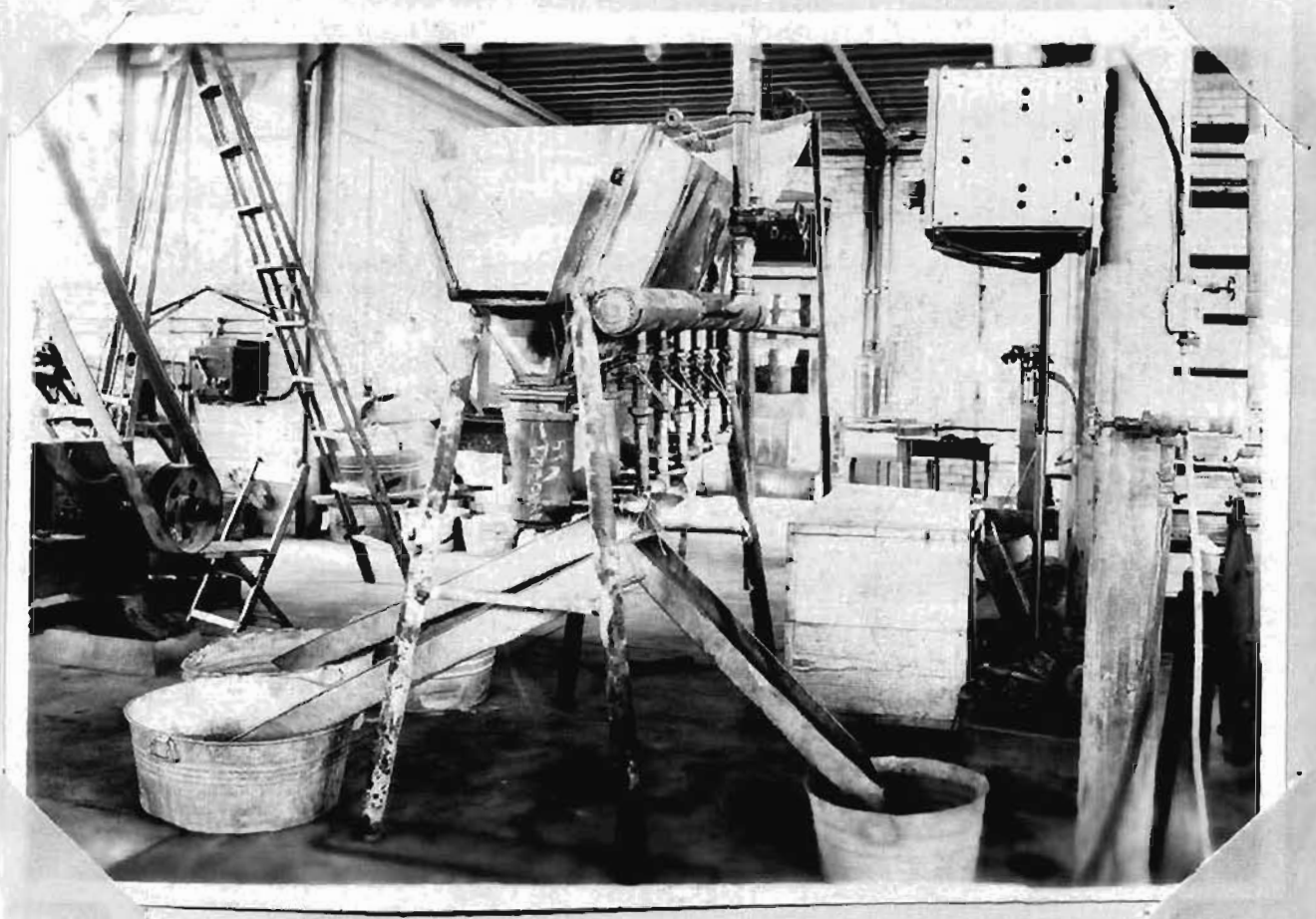


Figure 2-A. Richards Hindered-Settling Classifier.

A screen analysis of the material cleaned as above stated is given in Table II. This table gives the silica, calcite and fluorite content. An examination shows that the silica content decreases moderately down to 65 mesh; from 65 mesh downward the reverse condition is true. This increase in the silica content in the finer meshes makes the classification of the fine material, which at best is very hard to classify, doubly difficult.

We are now familiar with the ore to be classified and the following questions must be answered before we can intelligently proceed with classification:

(1) What are the settling ratios of silica, calcite and fluorite?

(2) How many spigot-products are required?

(3) What weight of material should each spigot let down?

An independent method is used to obtain answers to these questions. In other words, the method of procedure has been worked out independently of the methods given in the literature. The settling ratios will next be discussed.

Hindered-Settling Ratio of Calcite and Fluorite:

The glass classifier was first loaded with a 32 to 35 mesh fluorspar ore containing calcite and fluorite. The ore stratified, giving clean fluorite in the lower stratum and clean calcite in the upper stratum.

The test was continued to find the size of fluorite that would have an equal falling velocity with calcite. The classifier

Table II. Screen Analysis of Sludge Pond Tailings.

Screen Size	Weight Per cent	Assay Per cent SiO_2	Distribution of the SiO_2	Assay Per cent $CaCO_3$	Distribution of the $CaCO_3$	Assay Per cent CaF_2	Distribution of the CaF_2
-10 + 12	0.63	18.03	0.63	2.12	0.71	79.85	0.62
-12 + 14	1.57	17.64	1.56	2.28	1.90	80.08	1.57
-14 + 16	1.98	17.28	1.91	2.66	2.81	80.06	1.98
-16 + 20	2.06	15.32	1.78	3.20	3.49	81.48	2.08
-20 + 24	2.97	15.39	2.55	2.10	3.32	82.51	3.06
-24 + 28	3.06	15.69	2.67	1.97	3.19	82.34	3.13
-28 + 32	5.29	16.21	4.83	2.03	5.68	81.76	5.32
-32 + 35	4.40	15.74	3.87	2.06	4.81	82.20	4.53
-35 + 42	6.91	15.22	5.86	2.02	7.43	82.76	7.14
-42 + 48	6.98	14.51	5.63	1.97	7.33	83.52	7.31
-48 + 60	8.90	14.36	7.12	1.92	9.07	83.72	9.29
-60 + 65	8.06	14.23	6.39	1.79	7.66	83.98	8.44
-65 + 80	9.34	16.10	8.37	1.75	8.68	82.15	9.57
-80 + 100	12.62	18.22	12.80	1.59	10.64	80.19	12.63
-100 + 115	8.78	21.13	10.34	1.74	8.13	77.13	8.45
-115 + 150	5.79	20.83	6.73	1.70	5.24	77.47	5.60
-150 + 170	5.35	30.27	9.05	1.63	4.65	68.10	4.54
-170 + 200	1.80	27.31	2.74	1.96	1.87	70.73	1.59
-200 + 270	3.00	25.46	4.26	1.78	2.84	72.76	2.73
-270 + 325	0.51	31.93	0.91	2.04	0.55	66.03	0.42
	100.00	17.93	100.00	1.88	100.00	80.19	100.00

was charged with 32 to 35 mesh calcite and 35 to 42 mesh fluorite. Hydraulic water was again applied. The fluorite again stratified in the lower layer and the calcite in the upper layer. The classifier was again charged with the same 32 to 35 mesh calcite but with 42 to 48 mesh fluorite. Neither mineral stratified and thus the equal-falling condition was obtained, that is, 32 to 35 mesh calcite was equal-falling with 42 to 48 mesh fluorite. The ratio of the diameters of these equal-falling grains is determined by the following method:

The average diameters of the calcite and fluorite particles were calculated from the dimension in millimeters of the openings in the screens used. We have two square openings, A and B. The areas are a^2 and b^2. The average diameter is found by taking the square root of the average area.

The area of A = a^2

The area of B = b^2

The area of A and B = $\sqrt{\frac{a^2 + b^2}{2}}$

Substituting in this equation the diameter in millimeters of the 32, 35, 42 and 48 mesh screens we obtain the average diameter of the calcite and fluorite particles, for example:

(A) Average diameter of calcite particles = $\sqrt{\frac{0.495^2 + 0.417^2}{2}}$ = 0.458 mm.

(B) Average diameter of fluorite particles = $\sqrt{\frac{0.351^2 + 0.295^2}{2}}$ = 0.324 mm.

Dividing equation A by equation B we obtain the ratio of the diameters of the equal-falling grains:

$$\frac{0.458}{0.324} = 1.41 \text{ ratio.}$$

This experimentally determined ratio varies from the theoretical ratios obtained for both free and hindered-settling. The customary formula for free-settling ratio is:

$$\frac{D_1}{D_2} = \frac{(d_2 - 1)}{(d_1 - 1)}$$

Where D_1 and D_2 are the respective diameters and d_1 and d_2 are the respective densities of the particles.

In the case of hindered-settling the pulp density of ore and water in the sorting column will always vary as the amount of ore varies. The average specific gravity of ore and water in this sorting column is 1.5, as experimentally determined by Richards, where the bulk of material in the sorting column is quartz. Richards, thus implies that this number—1.5—is variable with the ore in the sorting column.

If this number is substituted in the above equation, we have a formula for the calculation of the hindered settling ratio, for example:

$$\frac{D_1}{D_2} = \frac{(d_2 - 1.5)}{(d_1 - 1.5)} .$$

Thus, substituting the densities of fluorite and calcite for d_2 and d_1, respectively, we obtain the following results:

The expression is: $\frac{\text{Fluorite } (3.15 - 1)}{\text{Calcite } (2.72 - 1)} = 1.25$ free-settling ratio, where the fluid (water) has a density of one. If 1.50 is used to represent the density of a quicksand pulp the expression is:

$$\frac{\text{Fluorite } (3.15 - 1.50)}{\text{Calcite } (2.72 - 1.50)} = 1.35 \text{ hindered-settling ratio.}$$

If the free-settling and hindered-settling ratios for quartz and galena are calculated in the same manner, 3.82 and 5.00, respectively are obtained.

Although the above calculations are not correct according to the revised formulas as found in the textbooks which give 3.99 free-settling and 6.95 hindered-settling ratio for quartz and galena, they have approximately the same relation to one another and serve to illustrate that when dealing with quartz and galena the difference between free and hindered-settling ratios indicates that hindered-settling has advantages to be desired. But, as shown above, the difference between free and hindered-settling ratios as found in fluorspar ore is not enough to justify much stress being put upon hindered-settling classifiers. In other words, the advantage of hindered-settling decreases as the difference in specific gravity between the mineral and the gangue decreases.

The stress should be placed upon the classifier that will eliminate surging within the pockets and do close-cut sizing of the respective minerals.

Ideal Classification:

By further study of the action of the glass classifier we are able to determine the theoretical number of spigots necessary for the classification of the ore at hand.

The results obtained in this experiment show that calcite of 32 to 35 mesh has equal-falling rate with fluorite of 42 to 48 mesh. This leaves a gap from 35 to 42 mesh in the screen scale. We know from experience that this gap is filled. What it is makes no difference from a practical standpoint because it is sized, and sizing here is the important item. Therefore, the upper half of this gap can be assumed to be filled with calcite and the lower half with fluorite. Thus the results obtained in the glass classifier supplemented by the above assumption is shown in Figure 3. Here we have pictured ideal classification of a calcite-fluorite ore.

The mesh of the spigots, as numbered in this figure, is assumed for illustration only and must not be confused with the data from the actual laboratory spigot products. In this figure we have assumed that Spigot 5 will let down 20 to 24 mesh calcite. Then from the results of the glass classifier 28 to 32 mesh fluorite will have an equal-falling rate.

The calcite is represented by a plain circle and the fluorite by a circle divided into quarters by cross-lines. The calcite and fluorite, which have been assumed to fill the gap, are represented in the same manner, except that the circle is a broken line. The mesh and deportment of the succeeding ideal spigots are shown in Spigots 6, 7, etc.

Figure 3. Ideal Classification of a Fluorite-Calcite Ore.

Figure #3

Ideal Classification of a Fluorite-Calcite Ore.

Spirals

The reason for starting with Spigot 5 is that the product of a spigot depends upon whether the original feed is classified or sized. If the original feed is classified the product of the first spigot is similar to subsequent spigots, but if the original feed is sized the first spigot should let down a concentrate. The next few spigots would have a tendency to do the same and are not so well adapted to the demonstration. Hence, the first spigot in this consideration is Spigot 5.

In Figure 3, just discussed, we have built up a premise for the calculation of the number of spigots necessary for hydraulic classification of an ore.

If the several spigots are followed through as shown, one can readily see that for a fluorspar ore the classifier must have a spigot for every one and one-half mesh in the sizing analysis of the feed. Now we have the number of spigots necessary, that is, an ore with sizes spreading over 15 meshes, would require ten spigots.

The next question to answer is the amount that each spigot should be allowed to let down. It may be seen that if a ton of feed to a classifier contains only one hundred pounds of equal-falling material, as indicated by Spigots 5, 6, etc. and the spigot is allowed to let down 300 pounds, classification is certain to be ruined. Hence the rate of flow of a spigot is an important factor.

The illustrations in Figure 3 are brought to a numerical basis in Table II-A, which is Table II cut down to a working basis for this illustration.

Table II-A. Illustration of Ideal Spigot Distribution of Silica, Calcite and Fluorite as Per Screen Analysis.

Screen Size	Weight Per cent	Assay Per cent SiO_2	Assay Per cent $CaCO_3$	Assay Per cent CaF_2	Ideal Spigot Number
- 10 + 12	0.63	18.03	2.12	79.85	
					1
- 12 + 14	1.57	17.64	2.28	80.08	
- 14 + 16	1.98	17.28	2.66	80.06	2
- 16 + 20	2.06	15.32	3.20	81.43	
					3
-20 + 24	2.97	15.39	2.10	82.51	
				82.34	4
- 24 + 28	3.06	15.69	1.97		
- 28 + 32	5.29	16.21	2.03	81.76	
					5
- 32 + 35	4.40	15.74	2.06	82.20	
- 35 + 42	6.91	15.22	2.02	82.76	6
- 42 + 48	6.98	14.51	1.97	83.52	
					7
- 48 + 60	8.90	14.36	1.92	83.78	
- 60 + 65	8.06	14.23	1.79	83.98	8
- 65 + 80	9.34	16.10	1.75	82.15	
					9
- 80 + 100	12.62	18.22	1.59	80.19	
-100 + 115	8.78	21.13	1.74	77.13	10
-115 + 150	5.79	20.83	1.70	77.47	
					11
-150 + 170	5.35	30.27	1.63	68.10	
-170 + 200	1.80	27.31	1.96	70.73	12
-200 + 270	3.00	25.46	1.78	72.76	
					13
-270 + 325	0.51	31.93	2.04	66.03	
					14
	100.00				15 - Overflow

It is assumed that if calcite and fluorite are given the proper consideration, quartz and quartzite will take care of themselves . Therefore, we may assume that the silica will stand one-half mesh above calcite and then spread through the same amount of space. In ideal classification (fed through a limiting screen) the first spigot would consist of the coarsest one and one-half mesh of fluorspar. The subsequent spigots are shown in Table II-A. When a line passes through a number, one-half of that number is used. All calculations are based upon 100 and are made as follows:

$$0.63 \times 79.85 + 1.57 \times \frac{80.08}{2} = 1.13$$ per cent by weight of the feed which may be let down by Spigot 1.

The second spigot contains one and one-half mesh fluorite, one and one-half mesh calcite, and one mesh of silica and is shown by the second irregular line drawn as illustrated in Table II-A. The calculation is as follows:

$$0.63 \times 18.03 + 0.63 \times 2.12 + 1.57 \times \frac{2.28}{2} + 1.57 \times \frac{80.08}{2} + 1.98 \times 80.06 =$$ 2.36 per cent weight of the feed that should be let down by Spigot 2.

Table III shows the distribution of the feed in respective spigots ideally performed and as actually performed in the laboratory. The first half of Table III shows a summary of the calculations of the amount and mesh that each of the 15 spigots theoretically should be allowed to let down.

"Mean Mesh," as used here indicates the center of that part of the screen scale which retained the predominating part of the sample. Fuller explanation of its meaning will be given later.

Table III. Distribution of Feed in Respective Spigots Ideally Performed and as Actually Performed.

Ideal Distribution of Feed in Respective Spigots				Observed Distribution of Feed in Respective Spigots		
Mean Mesh	Spigot Number	Weight Percent	Cumulative	Spigot Number	Weight Percent	Cumulative
10						
12						
	1	1.13	1.13			
14						
				1	.88	.88
16	2	2.36	3.49			
				2	1.31	2.19
				3	2.69	4.88
20				4	2.69	7.57
	3	3.42	6.91			
24				5	3.76	11.33
				6	1.26	12.59
				7	1.19	13.78
				8	.75	14.53
				9	.47	15.00
28	4	4.33	11.24	10	.28	15.28
				11	.25	15.53
				12	1.49	17.02
				13	1.82	18.84
32						
	5	6.92	18.16	14	2.00	20.84
35				15	3.94	24.78
				16	.94	25.72
				17	1.31	27.03
42	6	8.78	26.96			
				18	4.56	31.59
48						
	7	10.96	37.90			
60				19	15.40	46.99
				20	19.40	66.39
65	8	12.26	50.16			
				21	2.38	68.77
80						
	9	14.81	64.97	22	1.03	69.80
100				23	1.35	71.15
115	10	14.17	79.14			
				24	7.07	78.22
				25	9.26	87.48
				26	11.21	98.69
150						
	11	9.79	88.93			
170						
200	12	5.37	94.30	O'flow	1.31	100.00
	13	4.30	98.60			
270						
	14	1.24	99.84			
325	15	.16	100.00			

The second half of Table III shows the amount and the approximate size that each of the 26 spigots was allowed to let down, and is used as a comparison with the first half. The amount let down by the first 17 spigots equaled that which could be theoretically let down in six spigots. This is shown under "Cumulative" in the table. The facilities of classifying this ore did not permit a rigid following of the theoretical amounts as laid down in the first part of the table. Variation was accepted in order to make sure that at least part of the spigots did not exceed the theoretical amount. Also the number of spigots was carried to the extreme with the idea that important points were not likely to be overlooked.

Before taking up laboratory classification and a discussion of the results obtained it will be necessary to explain or define the terms "Mean Mesh" and the "Efficiency Number", and explain why the rather common term "Average Diameter" is not used.

Average Diameter:

Mineral particles produced by crushing and grinding show an almost infinite variety of shapes and sizes. No simple and accurate numerical expression of the dimensions of a single particle, nor of the average dimensions of a group is possible; the best that can be done in any case is an approximation which is ordinarily expressed as a single number, as though the particles were spheres or cubes. This number is called the DIAMETER OR SIZE of an individual particle, or the AVERAGE DIAMETER or AVERAGE SIZE of a group of particles.

Average diameter as used in some of the literature is calculated by some method of averaging the mean or equivalent diameters of a number of particles. The following is given by Perrott and Kinney:[1]

[1] Perrott, G. St. J., and Kinney, S. P., The meaning and microscopic measurement of average particle size; Jour. Am. Ceramic Soc., Vol. 6, p. 417, Feb. 1923.

1. Arithmetical mean $D = \frac{d_1 + d_2}{2}$.

2. Geometrical mean $D = \sqrt{d_1 d_2}$

3. Laschinger's mean $D = \frac{d_1 - d_2}{\log_e d_1 - \log_e d_2}$

4. Mellor's mean $D = \sqrt[3]{\frac{(d_1 + d_2)(d_1^2 + d_2^2)}{4}}$

5. Mean of form $D = \frac{4}{5}\left(\frac{d_1^5 - d_2^5}{d_1^4 - d_2^4}\right)$.

6. Von Reytt's mean $D = 0.435\ (d_1 + d_2)$

7. Number mean $D = \frac{\Sigma\, nd}{\Sigma\, n}$.

8. Length mean $D = \frac{\Sigma\, nd^2}{nd}$.

9. Surface mean $D = \frac{\Sigma nd^3}{\Sigma nd^2}$.

10. Volume mean $D = \frac{\Sigma nd^4}{\Sigma nd^3}$

To these should be added:

11. $D = \sqrt{\frac{\Sigma\, nd^2}{\Sigma\, n}}$.

12. $D = \sqrt[3]{\frac{\Sigma nd^3}{\Sigma\, n}}$,

where $\underline{D}$ is the mean diameter, $\underline{d_1}$ and $\underline{d_2}$ are the maximum and minimum mean particle diameters, respectively; $\underline{d}$ represents the successive mean particle diameters in a sizing operating and $\underline{n}$ the numerial frequency of the corresponding $\underline{d}$.

The magnitude of the value for AVERAGE PARTICLE SIZE depends upon the weighting of the different factors: (1) number; (2) length; (3) surface; and (4) volume of the particles of the several sizes. Thus the term AVERAGE PARTICLE SIZE is capable of various mathematical interpretations, many of which have little significance.

The formulas have been given as a matter of record, but they are thought to be of no value in this investigation and no attempt has been made to use AVERAGE DIAMETER in the sense as mentioned above. However, a related expression is required, and is here introduced. It is called MEAN MESH OR MEAN DIAMETER.

In order to define MEAN MESH and explain how it is derived, a premise must be established. Specific gravity increments must be obtained. Silica, calcite and fluorite fall within these respective increments. The distribution of each has to be weighted. To do this a force diagram is used (Figure 4). By this means the "off sizes", whether they be in the coarse or fine sizes are given the same consideration; that is, sizes which are smaller than the mean mesh are weighted the same as the sizes which are larger. The data used for further explanation is in Figure 4. It deals with Spigot 3. The mean mesh of the calcite and fluorite may be calculated in the same manner. The quantities representing the distribution of the silica

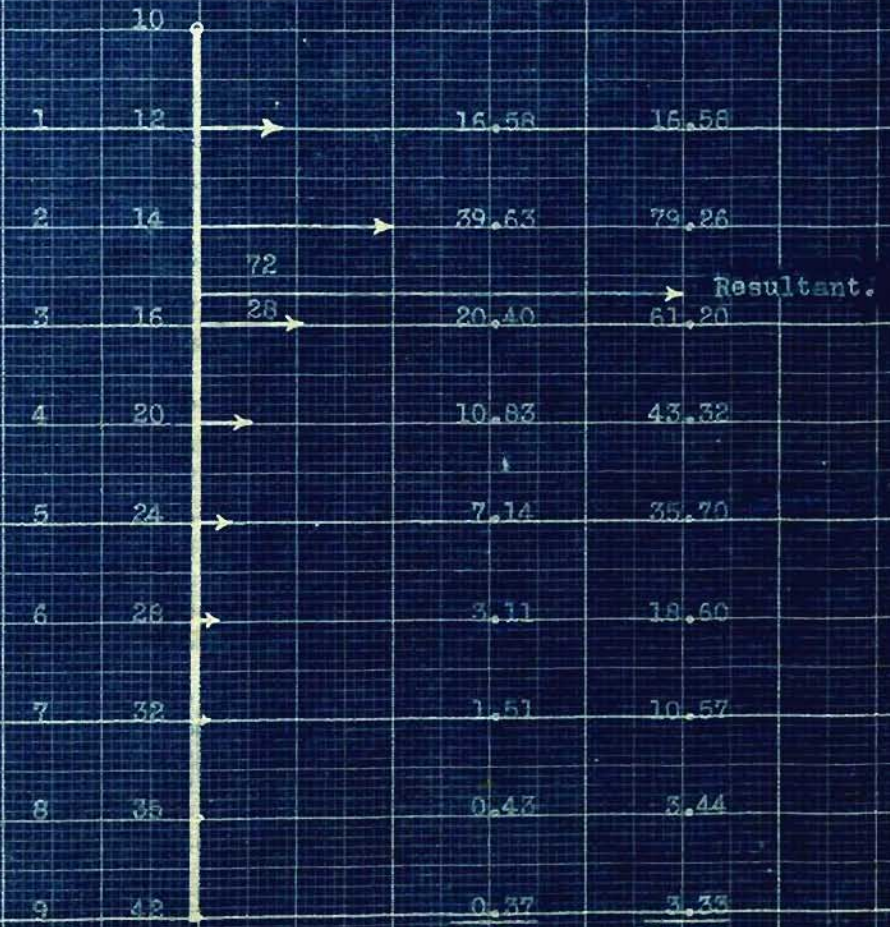
Figure 4. Force Diagram Illustrating "Mean Mesh" Calculations.

Figure No. 4

Force Diagram Illustrating

Mean Mesh Calculations.

Spigot No. 5 used for Illustration.



	Length of Mesh Lever Arm	Distribution of SiO_2 or Force.	Moment of SiO_2
1	12	16.58	16.58
2	14	39.63	79.26
3	16	20.40	61.20
4	20	10.83	43.32
5	24	7.14	35.70
6	28	3.11	18.60
7	32	1.51	10.57
8	36	0.43	3.44
9	42	0.37	3.33
		100.00	272.06

272.06 ÷ 100 = 2.72 Mean Mesh. (Mean Radius)

	Diameter.	Mean Mesh. SiO_2
14 M	1.168 mm.	
16 M	0.991 mm.	0.991 mm.
	0.177 mm. Diff.	0.050 mm.
		1.041 mm.

0.177 x 0.28 = 0.050 mm.

Efficiency Number.

0.28 x 16.58 = 4.64
39.63
20.40
10.83
0.72 x 7.14 = 5.14
80.64

Calcite and Fluorite are calculated in a similar manner.

	SiO_2	$CaCO_3$	CaF_2
Mean Mesh	1.041	0.950	0.808 mm.
Ratio	1.288	1.178	1.0
Eff. No.	80.64	82.12	72.21

are treated as forces having a moment about the first sieve—in this instance 10 mesh. The sieves are equally spaced along the lever arm because, as has been said, it is desired to "weight" equally the off sizes in the coarse and in the fines. Thus we have a simple problem in mechanics to locate a resultant. The resultant locates the mean mesh. Then, by interpolation between the adjacent sieves the mean mesh is found.

After determining the mean mesh the examination is carried a step further for a criterion of good classification. Here again the force diagram is used. The proportioned forces in the two sieve spaces above, and in the two spaces below the mean mesh are added. This sum gives what is called the Efficiency Number. The spread of sizes has a ratio of 1 to 2. This spread in commercial sizing is often found in practice. Thus, the efficiency number is obtained. It is thought that the per cent of material distributed within a range of two sieves from the mean mesh gives an excellent criterion of classification.

Details of the calculation of MEAN MESH and EFFICIENCY NUMBER are given beneath the diagram in Figure 4.

Laboratory Classification:

The products of each spigot were given a detailed examination. A screen analysis was made with the double Tyler sieves, i.e., the scale was the fourth root of two. Each size thus obtained was given a sink-and-float assay, the silica, calcite and fluorite falling within their respective specific gravity increments. The results of the examination of each of the 27 products are given in Table IV, which consists of 27 individual screen analyses in each of which the double Tyler sieves were used.

Table V is a summary of the 27 products as shown in Table IV. It shows the percentage of the entire sample each spigot let down, the total assay of each spigot product, and the distribution of the silica, calcite and fluorite of the entire sample as found in each spigot product.

Figure 5, consisting of 14 blue prints, is supplementary to Table IV. The distribution of silica, calcite and fluorite, as given numerically in Table IV, is shown graphically in this figure. The results of the classification are presented in this manner to give a definite picture of the degree of classification of each of the 26 spigots and the overflow. The distribution of silica, calcite, and fluorite are, respectively, represented by the solid line, the dot-and-dash line and the broken line. The mesh is laid off on a vertical scale in which each sieve is given the same amount of space. The per cent distribution of silica, calcite and fluorite is plotted on each side of the vertical axis, thus making a symmetrical figure.

Table IV. Screen Analyses of the Spigot Products.

Spigot 1 - 0.88 per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	25.61	1.73	27.46	.89	38.80	97.38	25.50
-12 + 14	35.40	1.88	41.26	.56	33.75	97.56	35.31
-14 + 16	22.29	1.29	17.82	.45	17.08	98.26	22.40
-16 + 20	7.19	1.16	5.17	.46	5.63	98.38	7.23
-20 + 24	5.86	1.40	5.09	.28	2.79	98.32	5.89
-24 + 28	1.82	1.21	1.36	.30	.92	98.49	1.83
-28 + 32	1.44	1.89	1.69	.38	.93	97.73	1.44
-32 + 35	0.39	.61	.15	.15	.10	99.24	.40
	100.00	1.61	100.00	.59	100.00	97.80	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 2 - 1.31 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	12.22	6.73	23.24	2.12	24.85	91.15	11.67
-12 + 14	28.02	4.35	34.45	1.20	32.27	94.45	27.73
-14 + 16	24.16	2.84	19.39	.83	19.24	96.33	24.39
-16 + 20	16.38	2.36	10.93	.70	11.00	96.94	16.64
-20 + 24	9.25	2.43	6.35	.60	5.32	96.97	9.40
-24 + 28	5.18	1.89	2.77	.66	3.28	97.45	5.29
-28 + 32	2.97	1.93	1.62	.50	1.42	97.57	3.04
-32 + 35	.98	2.17	.60	1.30	1.22	96.53	.99
-35 + 42	.59	2.19	.37	1.46	.83	96.35	.60
-42 + 48	.25	3.97	.28	2.38	.57	93.65	.25
	100.00	3.54	100.00	1.04	100.00	95.42	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 3 - 2.69 per cent weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	3.70	25.24	16.58	.97	2.61	73.79	2.94
-12 + 14	15.40	14.50	39.63	3.05	34.13	82.45	13.65
-14 + 16	19.49	5.90	20.40	2.01	28.46	92.09	19.30
-16 + 20	20.28	3.01	10.83	1.04	15.32	95.95	20.93
-20 + 24	21.64	1.86	7.14	.75	11.79	97.39	22.66
-24 + 28	11.01	1.59	3.11	.62	4.96	97.79	11.58
-28 + 32	7.02	1.21	1.51	.40	2.04	98.39	7.43
-32 + 35	1.07	2.24	.43	.75	.58	97.01	1.11
-35 + 42	.39	5.28	.37	.38	.11	94.34	.40
	100.00	5.63	100.00	1.38	100.00	92.99	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 4 - 2.69 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	2.91	34.72	14.36	5.09	6.83	60.19	1.93
-12 + 14	9.25	20.54	26.99	3.62	15.45	75.84	7.72
-14 + 16	16.18	11.19	25.73	2.62	19.56	86.19	15.36
-16 + 20	16.18	4.33	9.95	4.28	31.96	91.39	16.29
-20 + 24	21.02	3.00	8.96	1.31	12.71	95.69	22.15
-24 + 28	14.30	2.94	5.97	.85	5.61	96.21	15.15
-28 + 32	11.85	2.50	4.21	.72	3.94	96.78	12.63
-32 + 35	4.11	2.29	1.34	.76	1.44	96.95	4.39
-35 + 42	2.68	2.71	1.03	.85	1.05	96.44	2.85
-42 + 48	1.07	7.05	1.07	1.66	.82	91.29	1.08
-48 + 60	.45	6.06	.39	3.03	.63	90.91	.45
	100.00	7.04	100.00	2.17	100.00	90.79	100.00

Table IV (Continued). Screen Analyses of the Spigot Products..

Spigot 5 - 3.76 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	.92	63.34	5.53	3.33	2.07	33.33	.35
-12 + 14	3.54	55.53	18.68	3.23	4.02	41.24	1.67
-14 + 16	6.99	29.37	19.50	6.07	21.60	64.56	5.16
-16 + 20	10.05	17.48	16.69	4.26	22.88	78.26	8.99
-20 + 24	17.47	9.87	16.39	1.71	15.20	88.42	17.66
-24 + 28	19.00	5.88	10.62	1.27	12.28	92.85	20.16
-28 + 32	21.23	3.67	7.40	.98	10.59	95.35	23.13
-32 + 35	8.95	2.54	2.16	.93	4.23	96.53	9.87
-35 + 42	6.90	2.33	1.53	.76	2.67	96.91	7.64
-42 + 48	2.75	2.54	.66	1.27	1.78	96.19	3.02
-48 + 60	1.32	2.64	.33	1.97	1.32	95.39	1.44
-60 + 65	.44	6.00	.25	4.00	.90	90.00	.45
-65 + 80	.44	6.19	.26	2.06	.46	91.75	.46
	100.00	10.53	100.00	1.97	100.00	87.50	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 6 - 1.26 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	.89	84.66	6.24	4.23	1.87	11.11	.12
-12 + 14	2.63	77.06	16.77	5.20	6.81	17.74	.54
-14 + 16	5.27	53.11	23.17	5.33	13.98	41.56	2.55
-16 + 20	8.27	28.69	19.64	4.32	17.79	66.99	6.45
-20 + 24	19.32	12.30	19.67	2.74	26.36	84.96	19.11
-24 + 28	20.83	4.62	7.96	1.29	13.38	94.09	22.81
-28 + 32	27.42	2.07	4.70	.76	10.38	97.17	31.02
-32 + 35	9.21	1.12	.85	.56	2.57	98.32	10.54
-35 + 42	4.23	1.35	.47	.67	1.41	97.98	4.82
-42 + 48	1.18	2.02	.20	2.43	1.43	95.55	1.31
-48 + 60	.42	4.26	.15	4.26	.89	91.48	.45
-60 + 65	.19	5.56	.09	25.00	2.36	69.44	.15
-65 + 80	.14	7.41	.09	11.11	.77	81.48	.13
	100.00	12.08	100.00	2.01	100.00	85.91	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 7 - 1.19 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	0.77	85.09	5.83	5.59	2.50	9.32	0.08
-12 + 14	1.78	77.86	12.49	5.07	5.23	17.07	.34
-14 + 16	4.15	54.72	20.47	5.02	12.07	40.26	1.92
-16 + 20	6.67	29.13	17.51	3.74	14.46	67.13	5.14
-20 + 24	15.75	13.04	18.51	2.30	20.99	84.66	15.30
-24 + 28	19.37	6.19	10.81	1.35	15.15	92.46	20.55
-28 + 32	25.66	3.47	8.02	.97	14.42	95.56	28.12
-32 + 35	11.50	2.61	2.70	.88	5.86	96.51	12.73
-35 + 42	8.74	2.54	2.00	.66	3.34	96.80	9.71
-42 + 48	2.85	2.55	.66	1.35	2.23	96.10	3.14
-48 + 60	1.55	3.14	.44	1.57	1.41	95.29	1.70
-60 + 65	.58	4.39	.22	3.57	1.20	92.04	.61
-65 + 80	.39	5.14	.18	3.60	.81	91.26	.41
-80 + 100	.24	7.45	.16	2.35	.33	90.20	.25
	100.00	11.10	100.00	1.73	100.00	87.17	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 8 - 0.75 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	0.45	90.74	3.95	4.63	1.10	4.63	0.02
-12 + 14	1.25	82.84	10.02	7.26	4.80	9.90	0.14
-14 + 16	2.48	66.33	15.92	6.50	8.52	27.17	0.77
-16 + 20	5.47	36.54	19.35	6.20	17.93	57.26	3.57
-20 + 24	11.89	16.94	19.50	3.19	20.05	79.87	10.82
-24 + 28	20.29	7.67	15.06	1.69	18.13	90.64	20.95
-28 + 32	29.00	3.41	9.57	1.01	15.50	95.58	31.58
-32 + 35	14.57	2.13	3.00	.76	5.85	97.11	16.12
-35 + 42	8.45	2.11	1.73	.67	2.99	97.22	9.36
-42 + 48	3.18	2.33	.72	1.03	1.73	96.64	3.50
-48 + 60	1.57	2.79	.42	1.19	.99	96.02	1.72
-60 + 65	.62	5.37	.32	2.68	.88	91.95	.65
-65 + 80	.45	4.81	.21	2.88	.69	92.31	.47
-80 + 100	.33	7.23	.23	4.82	.84	87.95	.33
	100.00	10.33	100.00	1.89	100.00	87.78	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 9 - 0.47 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	0.46	92.16	3.53	2.94	0.78	4.90	0.03
-12 + 14	1.51	90.12	11.33	3.89	3.37	5.99	0.10
-14 + 16	3.10	81.74	21.10	5.01	8.91	13.25	.48
-16 + 20	3.83	55.29	17.63	5.59	12.28	39.12	1.74
-20 + 24	13.05	22.61	24.57	3.97	29.71	73.42	11.11
-24 + 28	21.54	6.75	12.11	1.72	21.25	91.53	22.86
-28 + 32	33.92	2.50	7.06	.76	14.78	96.74	38.05
-32 + 35	13.46	1.25	1.40	.51	3.94	98.24	15.33
-35 + 42	6.53	1.26	.69	.55	2.06	98.19	7.43
-42 + 48	1.69	2.47	.35	1.36	1.32	96.17	1.88
-48 + 60	.64	2.82	.15	2.11	.77	95.07	.70
-60 + 65	.27	3.57	.08	5.36	.83	91.07	.29
	100.00	12.01	100.00	1.74	100.00	86.25	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 10 - 0.28 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	0.35	89.02	2.70	5.49	0.96	5.49	0.02
-12 + 14	1.24	87.72	9.42	7.49	4.62	4.79	.07
-14 + 16	2.10	82.78	15.05	4.03	4.21	13.19	.32
-16 + 20	3.30	54.10	15.45	12.64	20.77	33.26	1.27
-20 + 24	9.55	28.72	23.74	4.26	20.25	67.02	7.40
-24 + 28	17.27	10.37	15.50	2.19	18.83	87.44	17.47
-28 + 32	31.48	3.83	10.44	1.07	16.77	95.10	34.63
-32 + 35	15.30	2.41	3.19	.76	5.79	96.83	17.14
-35 + 42	11.80	2.33	2.38	.71	4.17	96.96	13.24
-42 + 48	4.04	2.53	.92	.78	1.57	96.69	4.52
-48 + 60	1.98	3.01	.52	.88	.87	96.11	2.20
-60 + 65	.70	4.20	.25	1.23	.43	94.57	.77
-65 + 80	.54	5.23	.24	1.55	.42	93.22	.58
-80 + 100	.35	6.74	.20	1.97	.34	91.29	.37
	100.00	11.55	100.00	2.01	100.00	86.44	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 11 - 0.25 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	0.28	91.54	2.35	4.23	0.70	4.23	0.01
-12 + 14	.83	93.72	7.12	3.86	1.90	2.42	0.02
-14 + 16	1.90	86.14	14.98	5.25	5.91	8.61	.19
-16 + 20	2.89	60.71	16.06	6.18	10.58	33.11	1.09
-20 + 24	8.51	28.56	22.26	4.23	21.34	67.21	6.54
-24 + 28	15.03	10.82	14.89	2.16	19.24	87.02	14.94
-28 + 32	30.55	4.63	12.95	1.19	21.54	94.18	32.93
-32 + 35	17.29	2.74	4.34	.82	8.40	96.44	19.08
-35 + 42	13.94	2.22	2.83	.71	5.86	97.07	15.48
-42 + 48	4.71	2.27	.98	.75	2.09	96.98	5.26
-48 + 60	2.37	2.68	.58	.83	1.17	96.49	2.62
-60 + 65	.83	3.33	.25	.95	.47	95.72	.91
-65 + 80	.51	4.20	.20	1.15	.35	94.65	.55
-80 + 100	.36	6.45	.21	2.15	.46	91.40	.38
	100.00	10.92	100.00	1.69	100.00	87.39	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 12 - 1.49 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-12 + 14	0.65	94.29	5.00	4.28	1.64	1.43	0.01
-14 + 16	1.62	92.57	12.25	4.00	3.81	3.43	.06
-16 + 20	2.45	82.66	16.54	5.25	7.57	12.09	.34
-20 + 24	5.79	52.96	25.08	5.53	18.84	41.51	2.79
-24 + 28	11.35	19.67	18.28	3.27	21.84	77.06	10.16
-28 + 32	32.84	5.87	15.74	1.49	28.79	92.64	35.35
-32 + 35	22.60	2.13	3.93	.73	9.71	97.14	25.52
-35 + 42	15.66	1.56	1.99	.50	4.61	97.94	17.82
-42 + 48	4.31	2.04	.72	.62	1.57	97.34	4.88
-48 + 60	1.85	2.25	.34	.71	.77	97.04	2.10
-60 + 65	.56	2.53	.12	1.43	.47	96.04	.62
-65 + 80	.32	3.71	.09	2.00	.38	94.29	.35
	100.00	12.25	100.00	1.70	100.00	86.05	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 13 - 1.82 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-12 + 14	0.37	96.16	2.98	3.50	.77	.34	.00
-14 + 16	.93	92.84	7.23	4.03	2.24	3.13	.03
-16 + 20	1.99	85.24	14.21	5.33	6.30	9.43	.22
-20 + 24	4.06	59.68	20.29	5.39	12.99	34.93	1.64
-24 + 28	7.75	27.98	18.16	3.78	17.39	68.24	6.12
-28 + 32	24.20	9.70	19.66	1.95	28.02	88.35	24.76
-32 + 35	22.12	4.35	8.06	1.11	14.58	94.54	24.21
-35 + 42	20.25	2.83	4.80	.78	9.38	96.39	22.60
-42 + 48	9.90	2.60	2.16	.75	4.41	96.65	11.08
-48 + 60	5.03	2.80	1.18	.69	2.06	96.51	5.62
-60 + 65	1.70	3.70	.53	.85	.86	95.45	1.88
-65 + 80	.89	4.57	.34	.90	.48	94.53	.97
-80 + 100	.81	5.96	.40	1.09	.52	92.95	.87
	100.00	11.94	100.00	1.68	100.00	86.38	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 14 - 2.00 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-14 + 16	0.63	88.97	5.18	3.80	.16	7.23	.05
-16 + 20	1.11	87.57	8.98	5.04	3.68	7.39	.09
-20 + 24	2.75	68.54	17.41	5.61	10.16	25.85	.81
-24 + 28	4.97	37.46	17.20	4.74	15.51	57.80	3.28
-28 + 32	20.67	15.81	30.19	2.26	30.76	81.93	19.33
-32 + 35	23.28	4.68	10.06	1.18	18.08	94.14	25.02
-35 + 42	25.30	2.73	6.38	.81	13.49	96.46	27.84
-42 + 48	12.07	2.01	2.24	.52	4.13	97.47	13.43
-48 + 60	5.65	2.35	1.23	.65	2.42	97.00	6.25
-60 + 65	1.83	2.79	.47	.57	.69	96.64	2.02
-65 + 80	1.15	3.34	.35	.68	.51	95.98	1.26
-80 + 100	.58	5.78	.31	1.07	.41	93.15	.62
	100.00	10.84	100.00	1.52	100.00	87.64	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 15 - 3.94 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-14 + 16	0.46	92.16	3.11	3.92	1.04	3.92	.02
-16 + 20	.71	93.04	4.84	3.90	1.60	3.06	.03
-20 + 24	1.90	86.69	12.08	4.85	5.33	8.46	.19
-24 + 28	2.55	67.22	12.57	4.94	7.29	27.84	.84
-28 + 32	10.43	32.38	24.76	3.78	22.82	63.84	7.87
-32 + 35	14.84	12.25	13.33	2.17	18.64	85.58	15.01
-35 + 42	24.63	6.25	11.29	1.26	17.96	92.49	26.92
-42 + 48	17.00	4.77	5.95	.97	9.54	94.26	18.93
-48 + 60	13.07	4.34	4.16	.89	6.73	94.77	14.64
-60 + 65	5.47	4.62	1.85	1.06	3.36	94.32	6.09
-65 + 80	4.68	8.27	2.84	.88	2.38	90.85	5.02
-80 + 100	2.55	7.49	1.40	.73	1.08	91.78	2.76
-100 + 115	1.02	10.43	.78	1.62	.96	87.95	1.06
-115 + 150	.41	17.37	.52	3.12	.74	79.51	.38
-150 + 170	.28	25.23	.52	3.24	.53	71.53	.24
	100.00	13.64	100.00	1.73	100.00	84.63	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 16 - 0.94 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-14 + 16	0.78	94.32	5.61	3.02	1.40	2.66	0.02
-16 + 20	.75	94.89	5.43	3.70	1.65	1.41	.01
-20 + 24	1.88	87.62	12.57	4.56	5.11	7.82	.17
-24 + 28	3.67	64.50	18.06	5.13	11.22	30.37	1.31
-28 + 32	12.79	25.42	24.80	3.31	25.23	71.27	10.70
-32 + 35	16.60	9.75	12.35	1.83	18.10	88.42	17.22
-35 + 42	30.90	4.91	11.58	1.11	20.44	93.98	34.07
-42 + 48	13.55	3.28	3.39	.78	6.30	95.94	15.26
-48 + 60	9.27	3.03	2.14	.67	3.70	96.30	10.48
-60 + 65	3.95	3.55	1.07	.74	1.74	95.71	4.44
-65 + 80	3.06	4.25	.99	.83	1.51	94.92	3.41
-80 + 100	1.88	6.53	.94	1.04	1.17	92.43	2.04
-100 + 115	.49	6.36	.24	4.49	1.31	89.15	.51
-115 + 150	.24	22.65	.42	4.41	.63	72.94	.21
-150 + 170	.19	28.49	.41	4.30	.49	67.21	.15
	100.00	13.10	100.00	1.68	100.00	85.22	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 17 - 1.31 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
- 14 + 16	0.43	92.44	3.47	4.07	1.00	3.49	0.02
- 16 + 20	.67	92.08	5.38	6.24	2.38	1.68	.01
- 20 + 24	1.47	86.89	11.13	6.80	5.69	6.30	.11
- 24 + 28	2.64	70.97	16.32	6.07	9.13	22.96	.70
- 28 + 32	11.39	29.39	29.17	4.02	26.06	66.59	8.74
-32 + 35	19.29	9.24	15.53	2.00	21.98	88.76	19.73
- 35 + 42	32.83	3.93	11.25	1.07	20.00	95.00	35.93
- 42 + 48	15.18	2.51	3.32	.73	6.31	96.76	16.93
- 48 + 60	9.98	2.72	2.37	.75	4.26	96.53	11.10
- 60 + 65	2.94	2.60	.67	.65	1.09	96.75	3.28
- 65 + 80	1.94	3.36	.57	.78	.86	95.86	2.14
- 80 + 100	.95	6.32	.52	1.53	.83	92.15	1.01
-100 + 115	.30	11.58	.30	2.39	.41	86.03	.30
	100.00	11.47	100.00	1.76	100.00	86.77	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 18 - 4.56 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-16 + 20	0.45	82.76	2.78	14.96	3.42	2.28	.01
-20 + 24	.94	91.23	6.40	5.92	2.83	2.85	.03
-24 + 28	1.71	82.23	10.49	6.48	5.63	11.29	.23
-28 + 32	5.84	48.51	21.14	5.60	16.63	45.89	3.17
-32 + 35	8.98	21.49	14.40	3.15	14.38	75.36	8.00
-35 + 42	20.66	10.21	15.74	1.99	20.90	87.80	21.43
-42 + 48	21.43	6.17	9.87	1.35	14.71	92.48	23.41
-48 + 60	15.76	2.65	3.12	.54	4.33	96.81	18.03
-60 + 65	8.53	6.27	3.99	1.13	4.90	92.60	9.33
-65 + 80	6.74	6.86	3.45	1.21	4.15	91.93	7.32
-80 + 100	5.21	8.68	3.37	1.15	3.05	90.17	5.55
-100 + 115	1.89	20.74	2.92	2.69	2.58	76.57	1.71
-115 + 150	.94	14.52	1.02	2.11	1.01	83.37	.93
-150 + 170	.63	16.86	.79	2.91	.93	80.23	.60
-170 + 200	.29	24.14	.52	3.76	.55	72.10	.25
	100.00	13.40	100.00	1.97	100.00	84.63	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 19 - 15.40 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-24 + 28	0.54	91.74	3.28	3.72	1.13	4.54	0.03
-28 + 32	2.12	74.95	10.55	4.69	5.60	20.36	.52
-32 + 35	3.38	46.12	10.35	4.21	8.01	49.67	2.02
-35 + 42	10.81	24.42	17.52	3.00	18.25	72.58	9.44
-42 + 48	15.67	13.79	14.33	1.97	17.38	84.24	15.87
-48 + 60	19.64	10.18	13.26	1.57	17.36	88.25	20.83
-60 + 65	16.80	8.92	9.98	1.32	12.48	89.76	18.13
-65 + 80	11.80	8.37	6.55	1.16	7.70	90.47	12.84
-80 + 100	11.08	8.61	6.33	1.04	6.49	90.35	12.04
-100 + 115	4.14	11.04	3.03	1.08	2.52	87.88	4.38
-115 + 150	1.98	11.44	1.50	1.19	1.33	87.37	2.08
-150 + 170	1.12	21.52	1.60	.97	.61	77.51	1.04
-170 + 200	.54	23.36	.84	1.23	.37	75.41	.49
-200 + 270	.38	34.94	.88	3.61	.77	61.45	.29
	100.00	15.07	100.00	1.78	100.00	83.15	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 20 - 19.40 Per cent Weight.

M e s h	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-28 + 32	0.63	49.02	2.15	3.01	1.01	47.97	0.36
-32 + 35	1.26	70.00	6.14	5.29	3.54	24.71	.37
-35 + 42	4.07	47.49	13.45	4.53	9.78	47.98	2.33
-42 + 48	9.05	27.83	17.52	3.27	15.70	68.90	7.45
-48 + 60	18,45	16.71	21.44	2.50	24.48	80.79	17.80
-60 + 65	19.26	11.47	15.37	1.79	18.29	86.74	19.95
-65 + 80	22.32	8.32	12.92	1.31	15.52	90.37	24.09
-80 + 100	16.42	5.80	6.62	.87	7.58	93.33	18.30
-100 + 115	5.38	6.21	2.32	.73	2.08	93.06	5.98
-115 + 150	1.75	7.31	.89	.84	.78	91.85	1.92
-150 + 170	.98	10.61	.72	1.55	.81	87.84	1.03
-170 + 200	.43	15.37	.46	1.88	.43	82.75	.42
	100.00	14.38	100. 00	1.88	100.00	83.74	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 21 - 2.38 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-32 + 35	0.49	83.55	2.20	7.35	2.05	9.10	0.06
-35 + 42	1.13	82.45	5.00	3.55	2.29	14.00	.20
-42 + 48	2.56	70.07	9.62	3.58	5.23	26.35	.85
-48 + 60	6.13	49.47	16.26	3.37	11.78	47.16	3.63
-60 + 65	12.31	29.60	19.54	3.09	21.69	67.31	10.41
-65 + 80	25.18	15.84	21.39	1.85	26.56	82.31	26.04
-80 + 100	31.70	9.38	15.94	1.11	20.06	89.51	35.64
-100 + 115	12.45	8.01	5.35	.84	5.96	91.15	14.26
-115 + 150	4.65	9.61	2.40	.89	2.36	89.50	5.23
-150 + 170	2.09	11.61	1.30	.85	1.01	87.54	2.30
-170 + 200	.69	15.23	.56	1.17	.46	83.60	.72
-200 + 270	.62	13.18	.44	1.57	.55	85.25	.66
	100.00	18.65	100.00	1.75	100.00	79.60	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 22 - 1.03 Per cent Weight.

M e s h	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-32 + 35	0.44	70.30	1.46	14.17	3.19	15.53	0.09
-35 + 42	1.15	72.47	3.94	4.45	2.62	23.08	0.35
-42 + 48	2.27	62.60	6.72	4.13	4.80	33.27	.98
-48 + 60	5.73	47.83	12.96	3.84	11.27	48.33	3.60
-60 + 65	9.25	33.52	14.67	3.14	14.87	63.34	7.62
-65 + 80	17.67	21.23	17.74	2.31	20.90	76.46	17.57
-80 + 100	30.80	14.42	21.00	1.53	24.12	84.05	33.66
-100 + 115	14.37	12.56	8.54	1.10	8.09	86.34	16.13
-115 + 150	8.29	12.93	5.07	1.08	4.58	85.99	9.27
-150 + 170	5.78	15.84	4.33	.73	2.16	83.43	6.27
-170 + 200	1.83	21.02	1.82	1.34	1.26	77.64	1.85
-200 + 270	1.87	14.15	1.25	1.24	1.19	84.61	2.06
-270 + 325	.55	19.36	.50	3.37	.95	77.27	.55
	100.00	21.15	100.00	1.95	100.00	76.90	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 23 - 1.35 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-35 + 42	0.99	64.49	2.96	3.27	1.67	32.24	0.42
-42 + 48	1.99	54.08	4.99	4.48	4.59	41.44	1.08
-48 + 60	4.57	45.08	9.56	3.28	7.72	51.64	3.08
-60 + 65	10.60	32.71	16.08	2.71	14.80	84.58	8.94
-65 + 80	14.74	23.10	15.80	2.21	16.79	74.69	14.39
-80 + 100	27.82	16.05	20.71	1.42	20.36	82.53	30.01
-100 + 115	15.65	15.53	11.28	1.37	11.05	83.10	17.00
-115 + 150	10.01	14.51	6.74	1.22	6.29	84.27	11.03
-150 + 170	7.44	18.14	6.26	1.67	6.40	80.19	7.80
-170 + 200	3.83	17.95	3.19	4.17	8.23	77.88	3.90
-200 + 270	1.81	21.38	1.79	1.46	1.36	77.16	1.83
-270 + 325	.55	25.22	.64	2.61	.74	72.17	.52
	100.00	21.56	100.00	1.94	100.00	76.50	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 24 - 7.07 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-48 + 60	1.09	77.29	3.30	4.84	2.52	17.87	0.27
-60 + 65	1.83	64.96	4.65	3.99	3.49	31.05	.79
-65 + 80	6.88	44.08	11.87	3.47	11.41	52.45	4.99
-80 + 100	24.96	26.60	25.98	2.46	29.36	70.94	24.47
-100 + 115	23.26	20.59	18.74	1.80	20.02	77.61	24.95
-115 + 150	15.36	17.83	10.71	1.55	11.38	80.62	17.12
-150 + 170	14.81	23.59	13.67	1.72	12.18	74.69	15.28
-170 + 200	3.53	23.30	3.22	1.70	2.87	75.00	3.66
-200 + 270	6.70	23.12	6.06	1.73	5.54	75.15	6.96
-270 + 325	1.58	29.09	1.80	1.63	1.23	69.28	1.51
	100.00	25.56	100.00	2.09	100.00	72.35	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 25 - 9.26 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-48 + 60	1.12	80.18	3.72	4.50	2.69	15.32	0.23
-60 + 65	1.97	64.29	5.25	4.08	4.28	31.63	.84
-65 + 80	7.54	44.14	13.80	3.49	14.00	52.37	5.35
-80 + 100	22.61	21.09	19.78	1.87	22.50	77.04	23.54
-100 + 115	21.86	20.88	18.93	1.75	20.36	77.37	22.86
-115 + 150	17.49	18.47	13.40	1.49	13.87	80.04	18.93
-150 + 170	14.75	21.77	13.01	1.59	12.47	77.14	15.33
-170 + 200	4.72	25.67	5.03	1.58	3.97	72.75	4.64
-200 + 270	6.74	20.95	5.85	1.25	4.48	77.80	7.09
-270 + 325	1.20	24.68	1.23	2.16	1.38	73.16	1.19
	100.00	24.11	100.00	1.88	100.00	74.01	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

Spigot 26 - 11.21 Per cent Weight.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-48 + 60	0.45	87.15	1.10	4.28	0.88	8.57	0.06
-60 + 65	.92	77.08	1.98	4.86	2.04	18.06	.28
-65 + 80	3.63	60.60	6.15	4.28	7.10	35.12	2.06
-80 + 100	17.93	41.73	20.90	2.44	20.00	55.83	16.14
-100 + 115	23.05	31.76	20.45	2.35	24.77	65.89	24.49
-115 + 150	17.71	28.49	14.09	2.19	17.73	69.32	19.80
-150 + 170	18.43	41.60	21.42	1.53	12.89	56.87	16.89
-170 + 200	4.83	26.86	3.62	1.64	3.62	71.50	5.57
-200 + 270	11.53	26.77	8.62	1.73	9.12	71.50	13.29
-270 + 325	1.52	39.40	1.67	2.66	1.85	57.94	1.42
	100.00	35.80	100.00	2.19	100.00	62.01	100.00

Table IV (Continued). Screen Analyses of the Spigot Products.

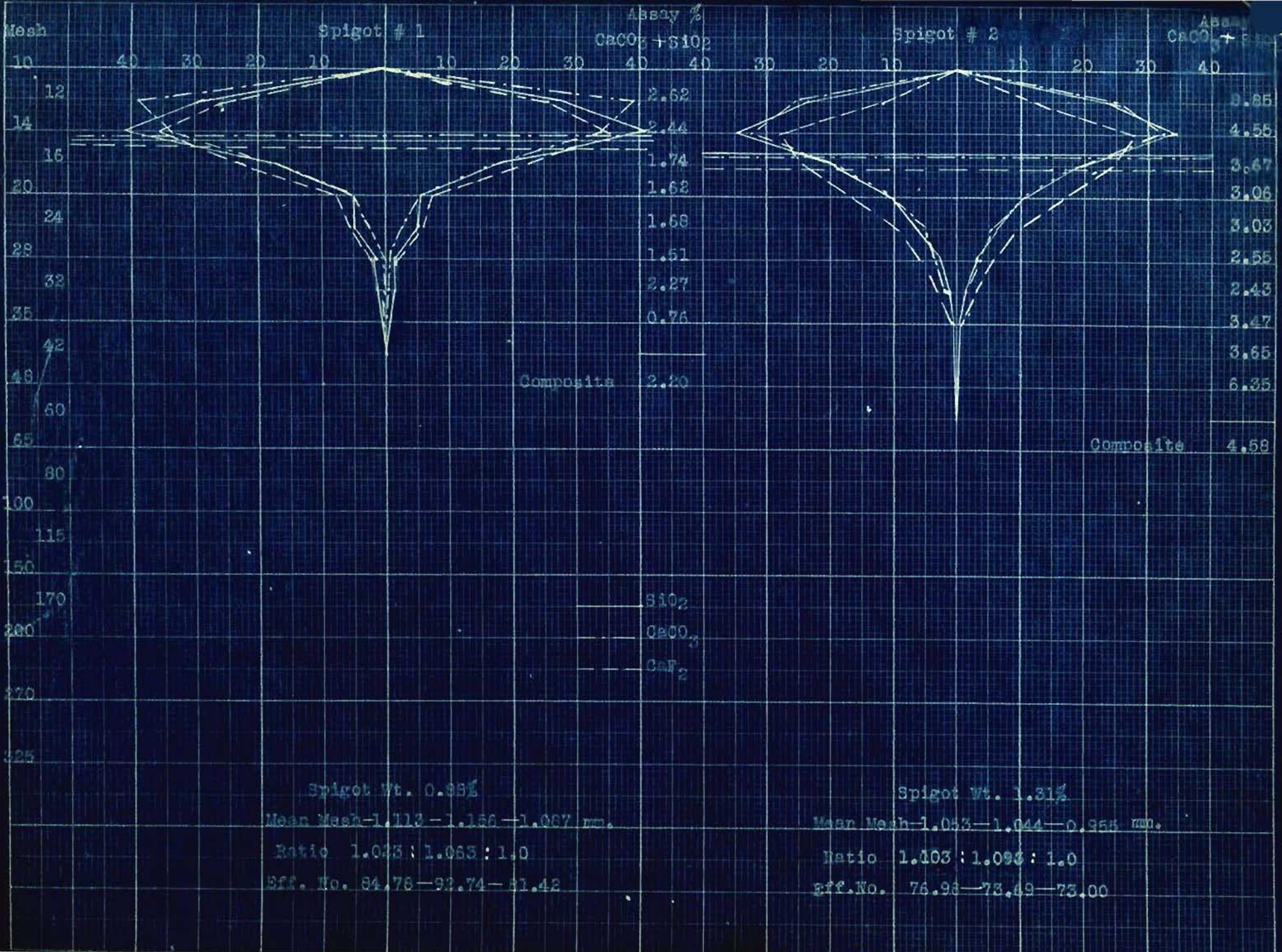
Overflow - 1.31 Per cent Weight.

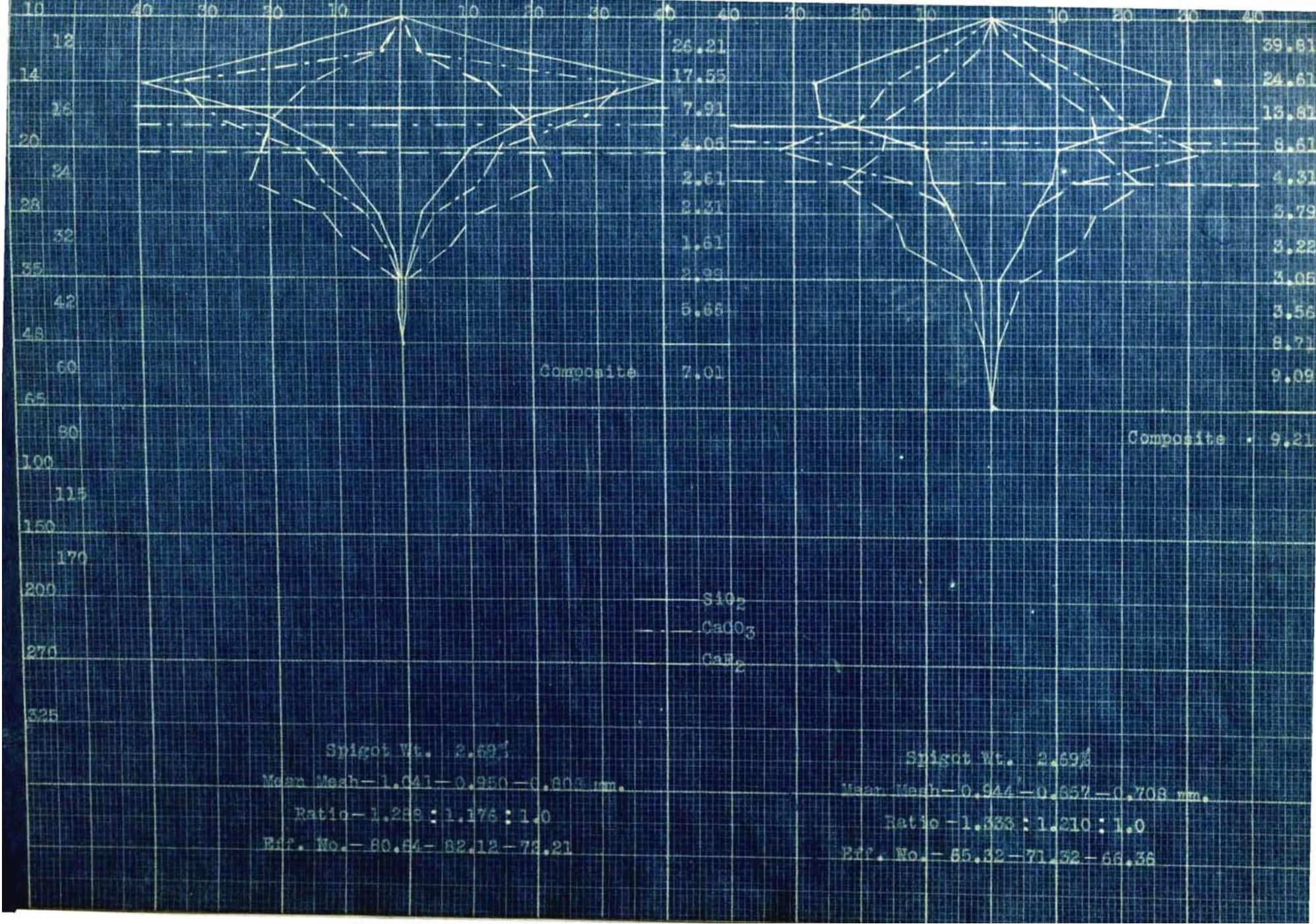
M e s h	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-80 + 100	1.10	66.45	1.85	0.97	0.39	32.58	0.62
-100 + 115	4.58	68.92	7.94	3.54	6.00	27.54	2.19
-115 + 150	5.25	56.49	7.45	3.69	7.17	39.82	3.63
-150 + 170	19.93	48.09	24.09	2.94	21.68	48.97	16.97
-170 + 200	23.24	40.71	23.78	3.14	27.00	56.15	22.69
-200 + 270	37.87	29.91	28.47	2.44	34.19	67.65	44.55
-270 + 325	8.03	31.81	6.42	1.20	3.57	66.99	9.35
	100.00	39.78	100.00	2.70	100.90	57.52	100.00

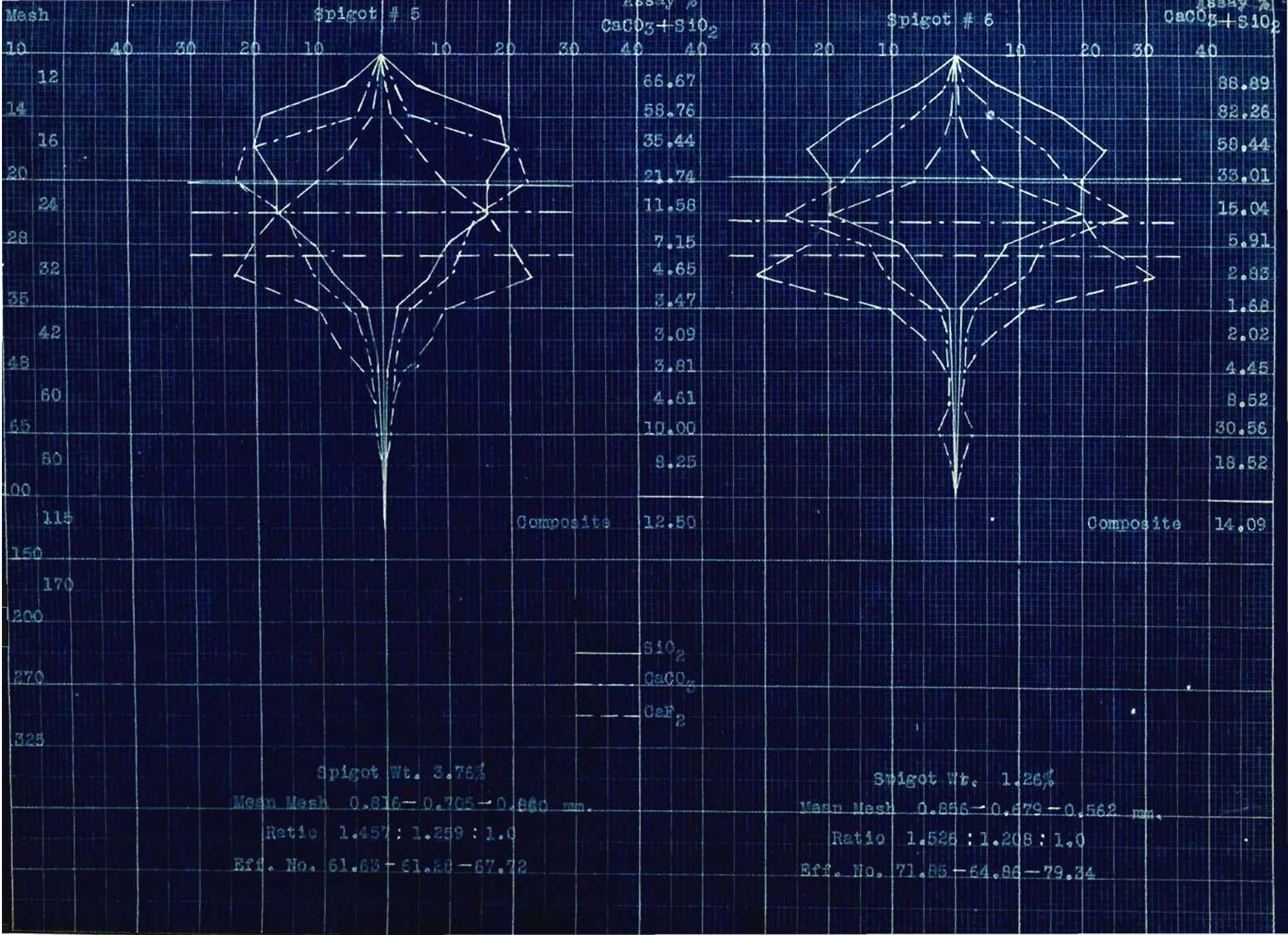
Table V. Summary of Table IV - Distribution of SiO_2, $CaCO_3$, CaF_2 Per Spigot.

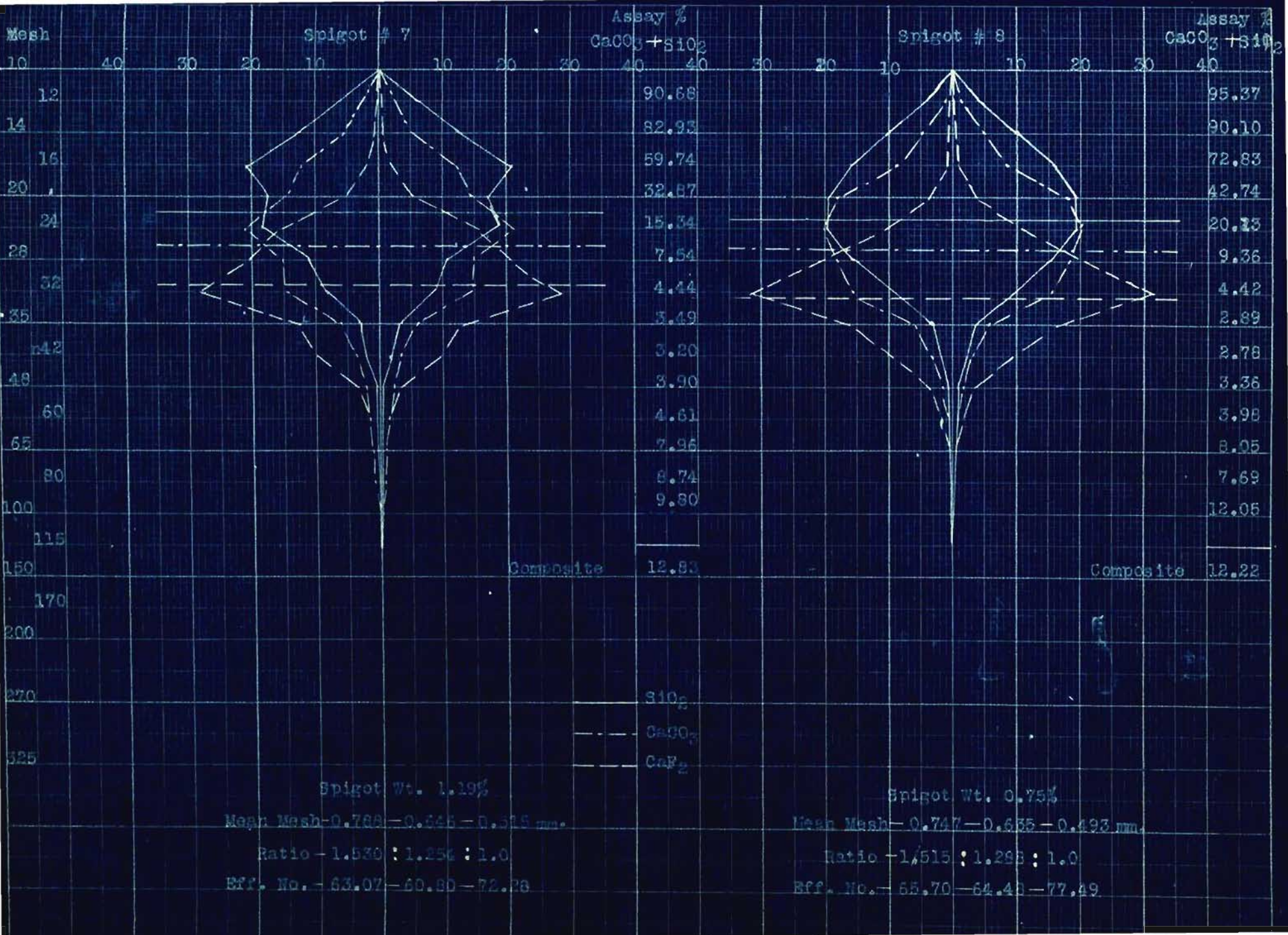
Spigot Number	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
1	0.88	1.61	0.08	0.59	0.28	97.80	1.07
2	1.31	3.54	0.26	1.04	.73	95.92	1.57
3	2.69	5.63	.84	1.38	1.98	92.99	3.12
4	2.69	7.04	1.06	2.17	3.11	90.79	3.05
5	3.76	10.53	2.21	1.97	3.94	87.50	4.10
6	1.26	12.08	.85	2.01	1.35	85.91	1.35
7	1.19	11.10	.74	1.73	1.10	87.18	1.29
8	.75	10.33	.43	1.89	.75	87.78	.82
9	.47	12.01	.31	1.74	.44	86.25	.50
10	.28	11.55	.18	2.01	.30	86.44	.30
11	.25	10.92	.15	1.69	.22	87.39	.27
12	1.49	12.25	1.02	1.70	1.35	86.05	1.60
13	1.82	11.94	1.21	1.68	1.63	86.38	1.96
14	2.00	10.84	1.21	1.52	1.62	87.64	2.10
15	3.94	13.64	2.99	1.73	3.63	84.63	4.16
16	.94	13.10	.69	1.68	.84	85.20	1.00
17	1.31	11.47	.84	1.76	1.23	86.77	1.42
18	4.56	13.40	3.40	1.97	4.78	84.63	4.81
19	15.40	15.70	12.93	1.78	14.59	83.15	15.98
20	19.40	14.38	15.53	1.88	19.40	83.74	20.26
21	2.38	18.65	2.47	1.75	2.22	79.60	2.36
22	1.03	21.15	1.21	1.95	1.07	76.90	.99
23	1.35	21.56	1.62	1.94	1.39	76.50	1.29
24	7.07	25.56	10.07	2.09	7.86	72.35	6.38
25	9.26	24.11	12.46	1.88	9.25	74.01	8.55
26	11.21	35.80	22.34	2.19	13.06	62.01	8.67
Overflow	1.31	39.78	2.90	2.70	1.88	57.54	.94
	100.00	17.93	100.00	1.88	100.00	80.19	100.00

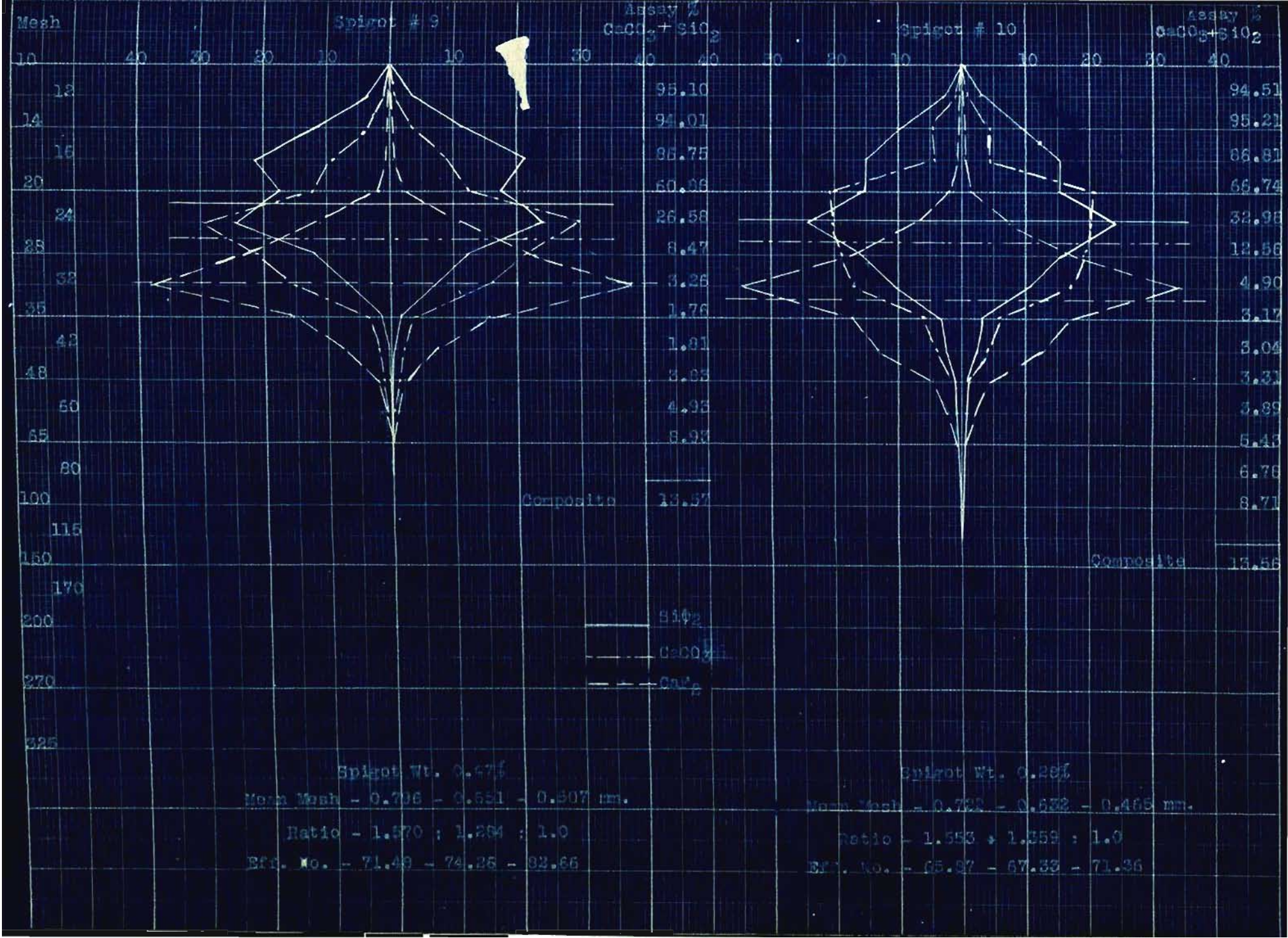
Figure 5. Classification Diagrams, Consisting of 14 Blue Prints.

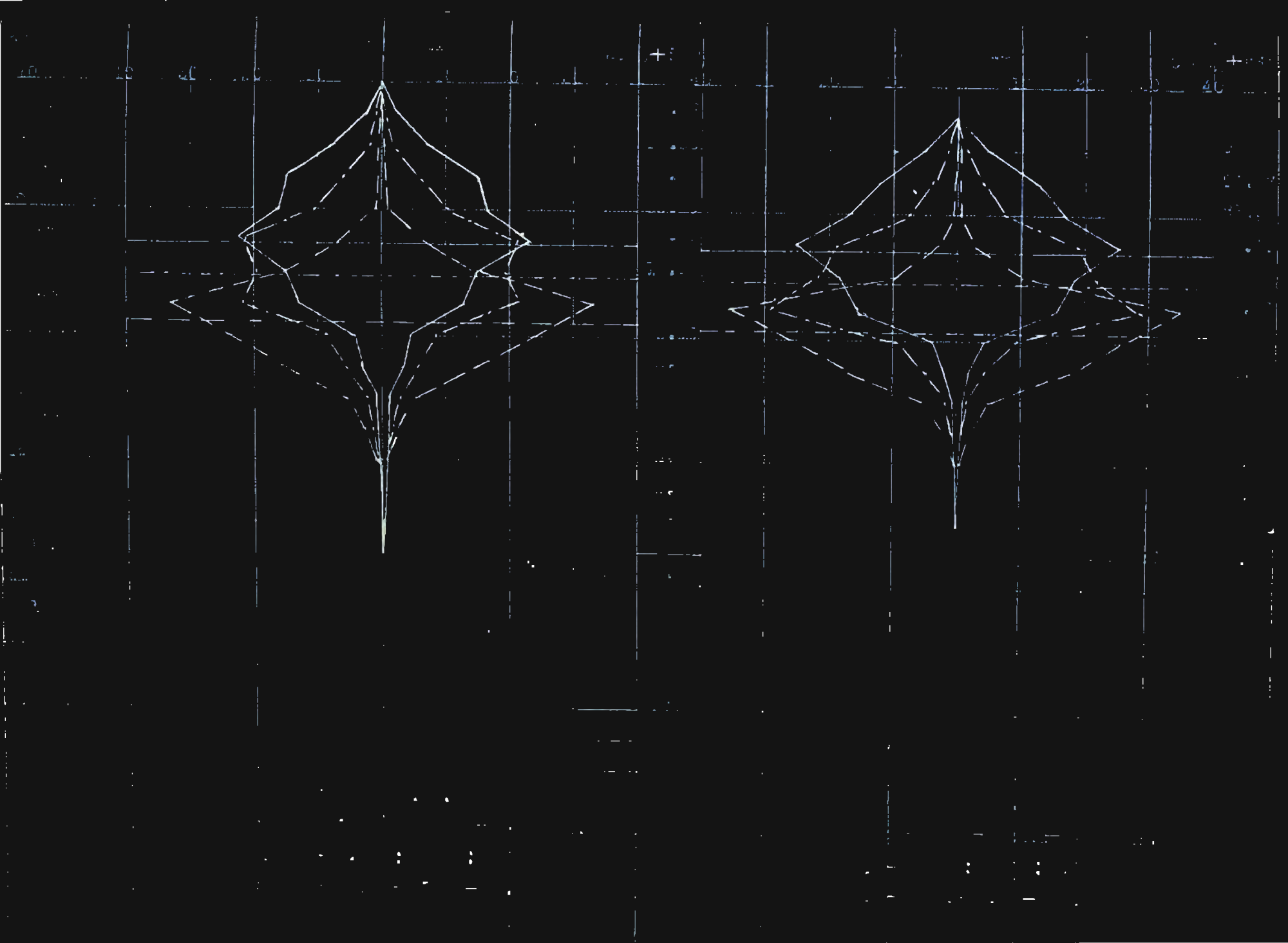

Mesh
Spigot # 1
Assay % $CaCO_3$ + SiO_2
10 40 30 20 10 10 20 30 40
12
14
16
20
24
28
32
35
42
48
60
65
80
100
115
150
170
200
270
325
2.62
2.44
1.74
1.62
1.68
1.51
2.27
0.76
Composite 2.20
Spigot # 2
40 30 20 10 10 20 30 40
3.85
4.55
3.67
3.06
3.03
2.55
2.43
3.47
3.65
6.35
Composite 4.68
SiO_2
$CaCO_3$
CaF_2
Spigot Wt. 0.88%
Mean Mesh-1.113—1.166—1.067 mm.
Ratio 1.043 : 1.063 : 1.0
Eff. No. 84.76—93.74—81.42
Spigot Wt. 1.31%
Mean Mesh-1.053—1.044—0.955 mm.
Ratio 1.103 : 1.093 : 1.0
Eff.No. 76.98—73.69—73.00

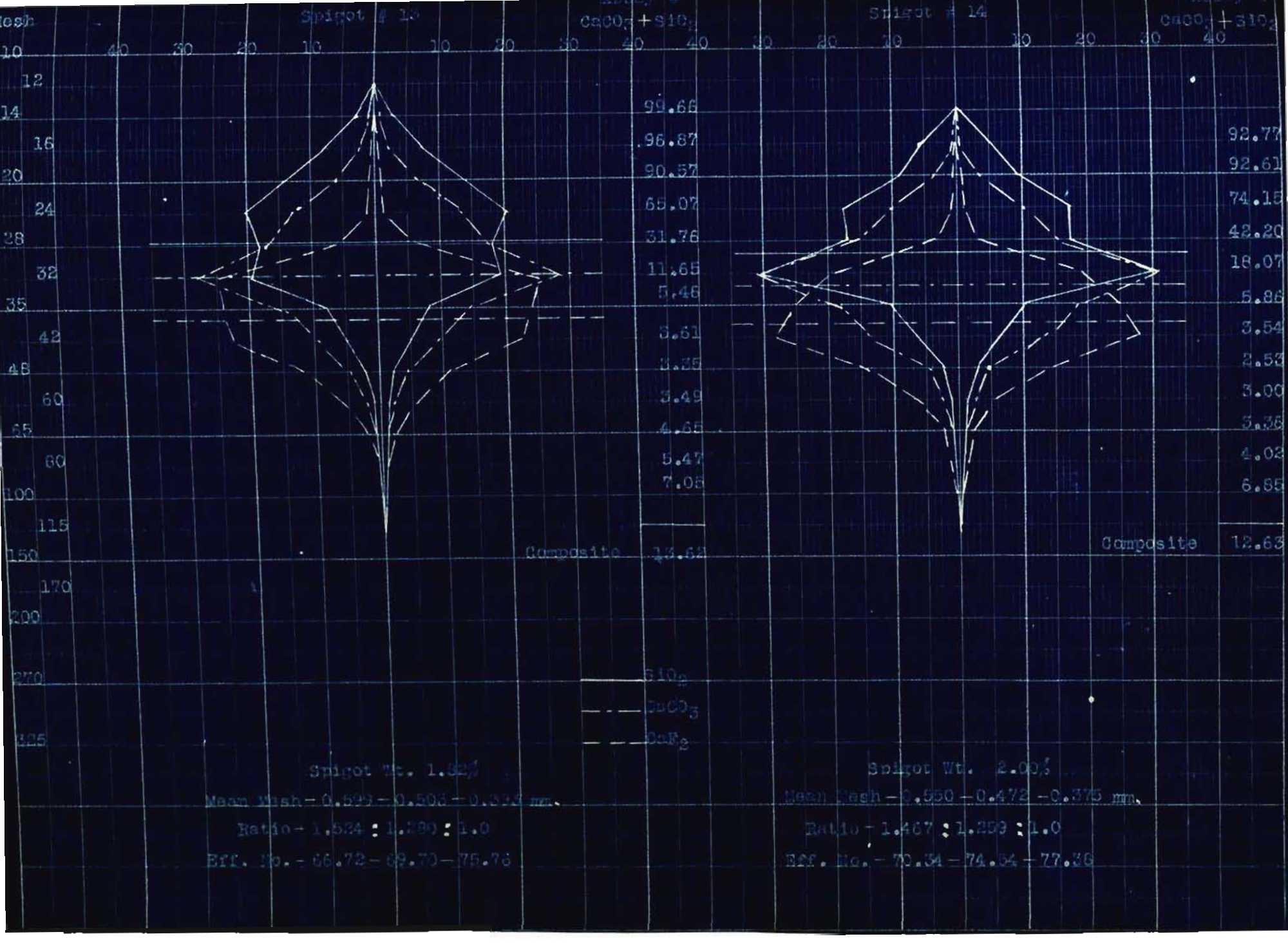

10 40 30 30 10 10 30 30
12
14
16
20
24
28
32
35
42
48
60
65
80
100
115
150
170
200
270
325
Composite 7.01
SiO_2
$CaCO_3$
CaH_2
Spigot Wt. 2.62%
Mean Mesh—1.041—0.950—0.808 mm.
Ratio—1.288 : 1.176 : 1.0
Eff. No.—80.84—82.12—78.21
26.21
17.55
7.91
4.05
2.61
2.31
1.61
2.99
5.66
40 30 30 10 10 30 40
39.81
24.61
13.80
8.61
4.31
3.79
3.22
3.05
3.56
8.71
9.09
Composite 9.21
Spigot Wt. 2.69%
Mean Mesh—0.944—0.857—0.708 mm.
Ratio—1.333 : 1.210 : 1.0
Eff. No.—65.32—71.32—66.36

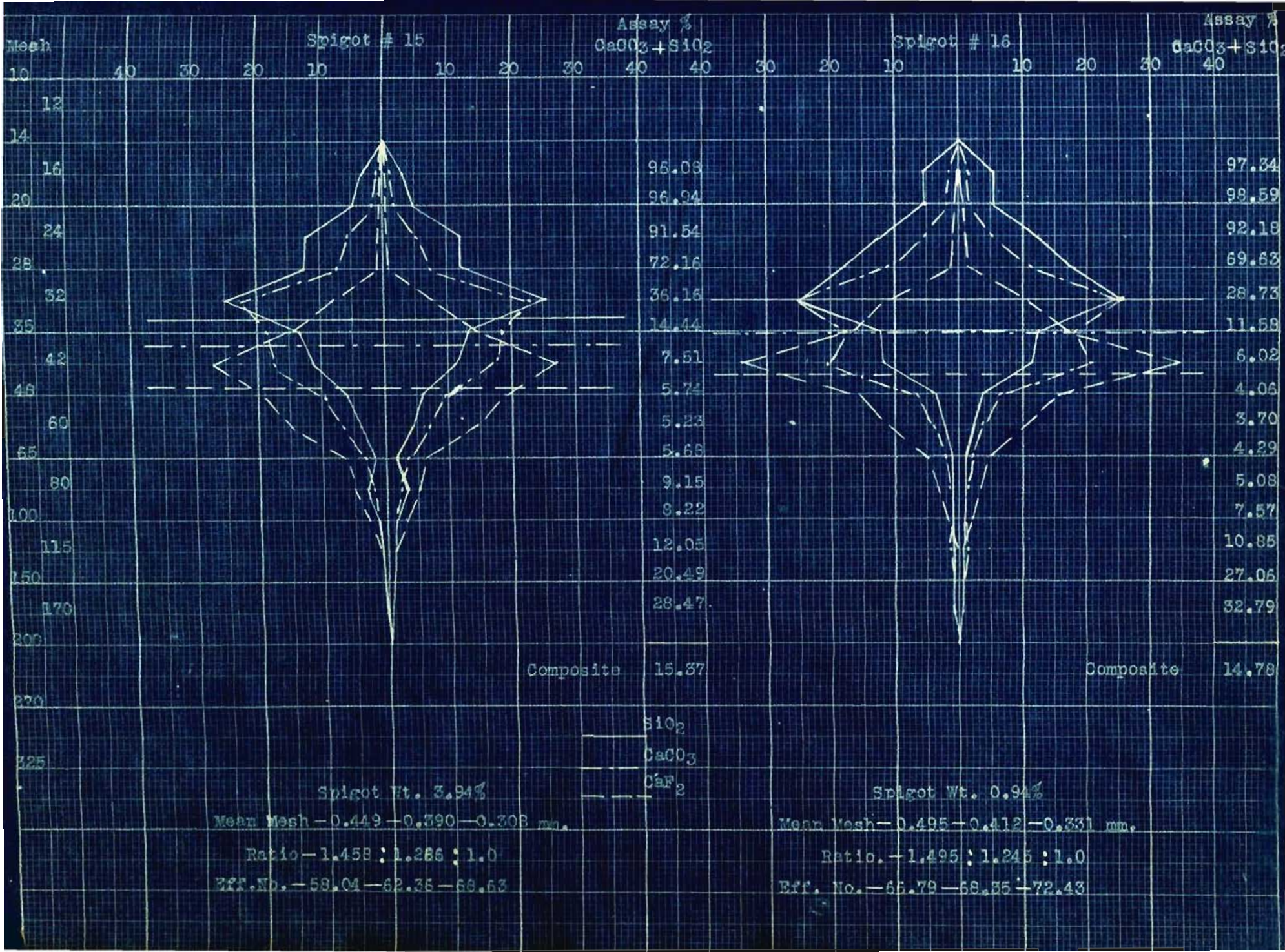

Mesh
Spigot # 5
Assay % $CaCO_3 + SiO_2$
Spigot # 6
Assay % $CaCO_3 + SiO_2$
10 40 30 20 10 10 20 30 40 40 30 20 10 10 20 30 40
12 66.67 88.89
14 58.76 82.26
16 35.44 58.44
20 21.74 33.01
24 11.56 15.04
28 7.15 5.91
32 4.65 2.83
35 3.47 1.68
42 3.09 2.02
48 3.81 4.45
60 4.61 8.52
65 10.00 30.56
80 8.25 18.52
100
115 Composite 12.50 Composite 14.09
150
170
200
270
325
SiO_2
$CaCO_3$
CaF_2
Spigot Wt. 3.76%
Mean Mesh 0.816 — 0.705 — 0.860 mm.
Ratio 1.457 : 1.259 : 1.0
Eff. No. 61.65 — 61.28 — 67.72
Spigot Wt. 1.26%
Mean Mesh 0.856 — 0.679 — 0.562 mm.
Ratio 1.526 : 1.208 : 1.0
Eff. No. 71.85 — 64.86 — 79.34

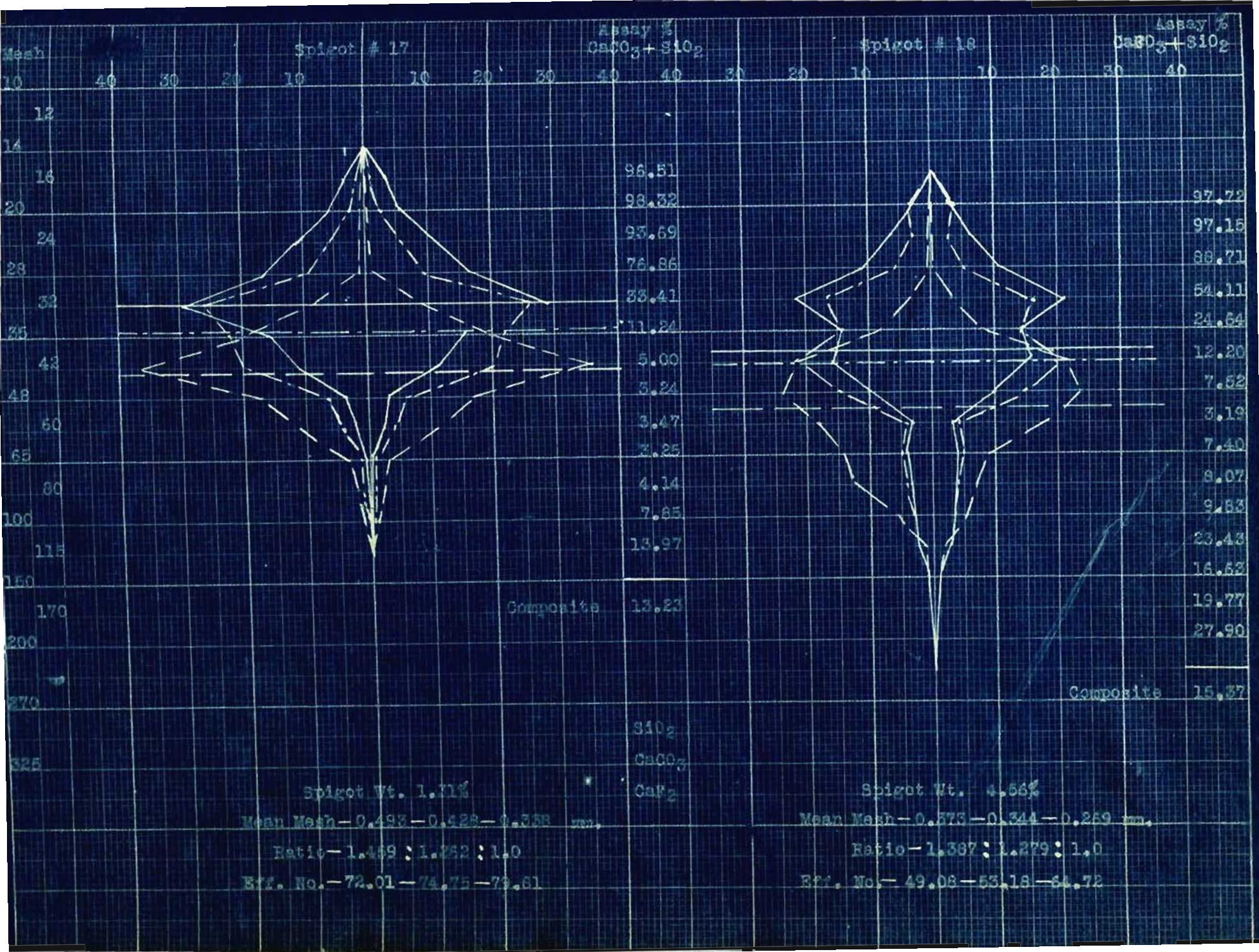

Mesh
Spigot # 7
Assay % $CaCO_3 + SiO_2$
Spigot # 8
Assay % $CaCO_3 + SiO_2$
10 40 30 20 10 10 20 30 40 40 30 20 10 10 20 30 40
12 90.68 95.37
14 82.93 90.10
16 59.74 72.83
20 32.87 42.74
24 15.34 20.13
28 7.64 9.36
32 4.44 4.42
35 3.49 2.89
42 3.20 2.78
48 3.90 3.36
60 4.61 3.98
65 7.96 8.05
80 8.74 7.69
100 9.80 12.05
115
150 Composite 12.83 Composite 12.22
170
200
270
325
SiO_2
$CaCO_3$
CaF_2
Spigot Wt. 1.19%
Mean Mesh-0.788—0.646—0.515 mm.
Ratio - 1.530 : 1.256 : 1.0
Eff. No. - 63.07—60.80—72.28
Spigot Wt. 0.75%
Mean Mesh— 0.747—0.635—0.493 mm.
Ratio - 1.515 : 1.288 : 1.0
Eff. No.— 65.70—64.48—77.49

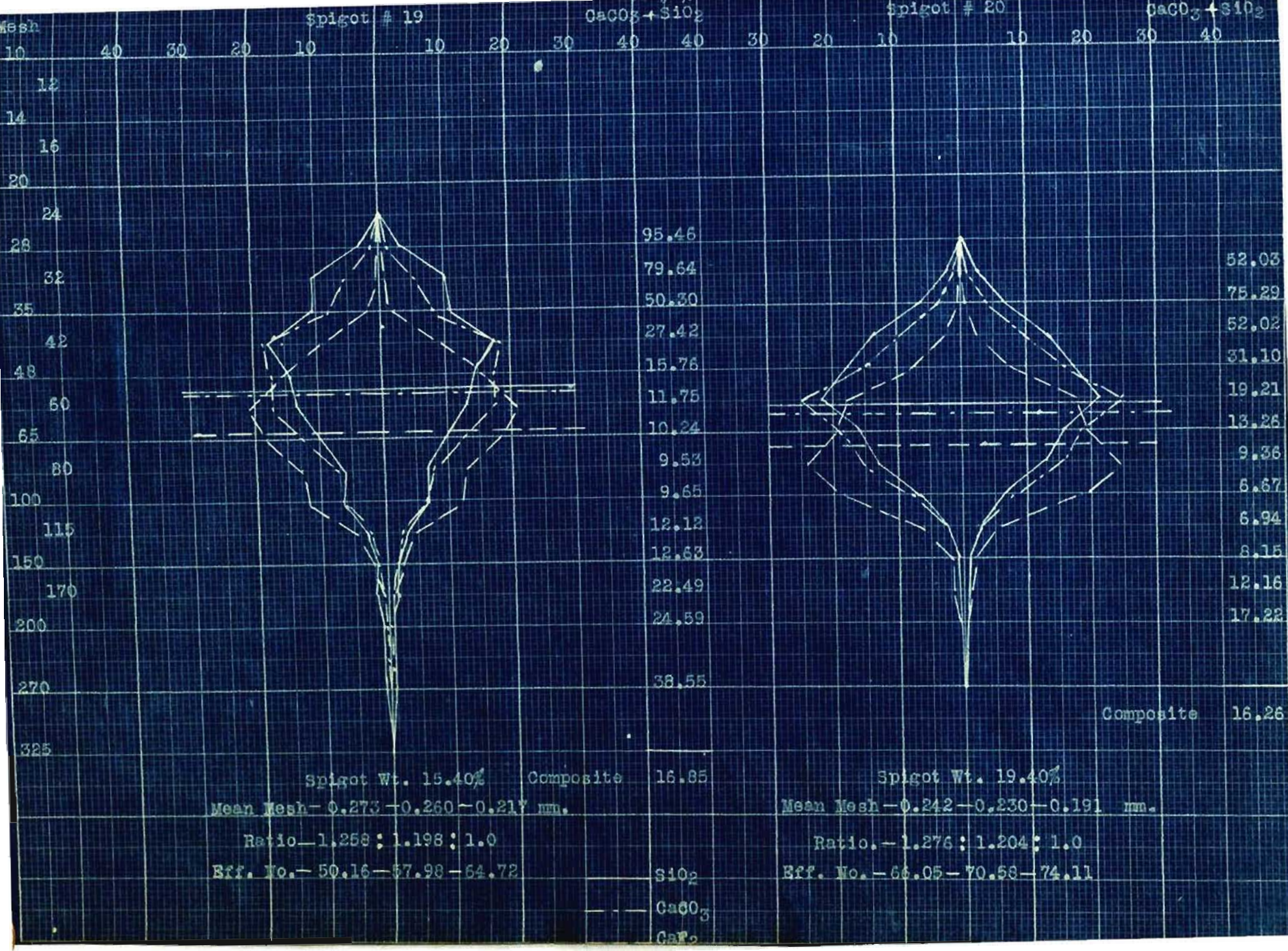

Mesh
Spigot # 9
Assay % $CaCO_3 + SiO_2$
Spigot # 10
Assay % $CaCO_3 + SiO_2$
10 40 30 20 10 10 30 40 40 50 20 10 10 30 20 30 40
12 95.10 94.51
14 94.01 95.21
16 88.75 88.81
20 60.08 66.74
24 26.58 32.98
28 8.47 12.56
32 3.26 4.90
35 1.76 3.17
42 1.01 3.04
48 3.05 3.31
60 4.95 3.89
65 8.93 5.43
80 6.76
100 Composite 13.57 8.71
115
150 Composite 15.56
170
200
270
325
SiO_2
$CaCO_3$
CaC_2
Spigot Wt. 0.47%
Mean Mesh - 0.706 - 0.551 - 0.307 mm.
Ratio - 1.570 : 1.284 : 1.0
Eff. No. - 71.49 - 74.26 - 82.66
Spigot Wt. 0.28%
Mean Mesh - 0.722 - 0.532 - 0.465 mm.
Ratio - 1.553 : 1.359 : 1.0
Eff. No. - 65.97 - 67.33 - 71.36

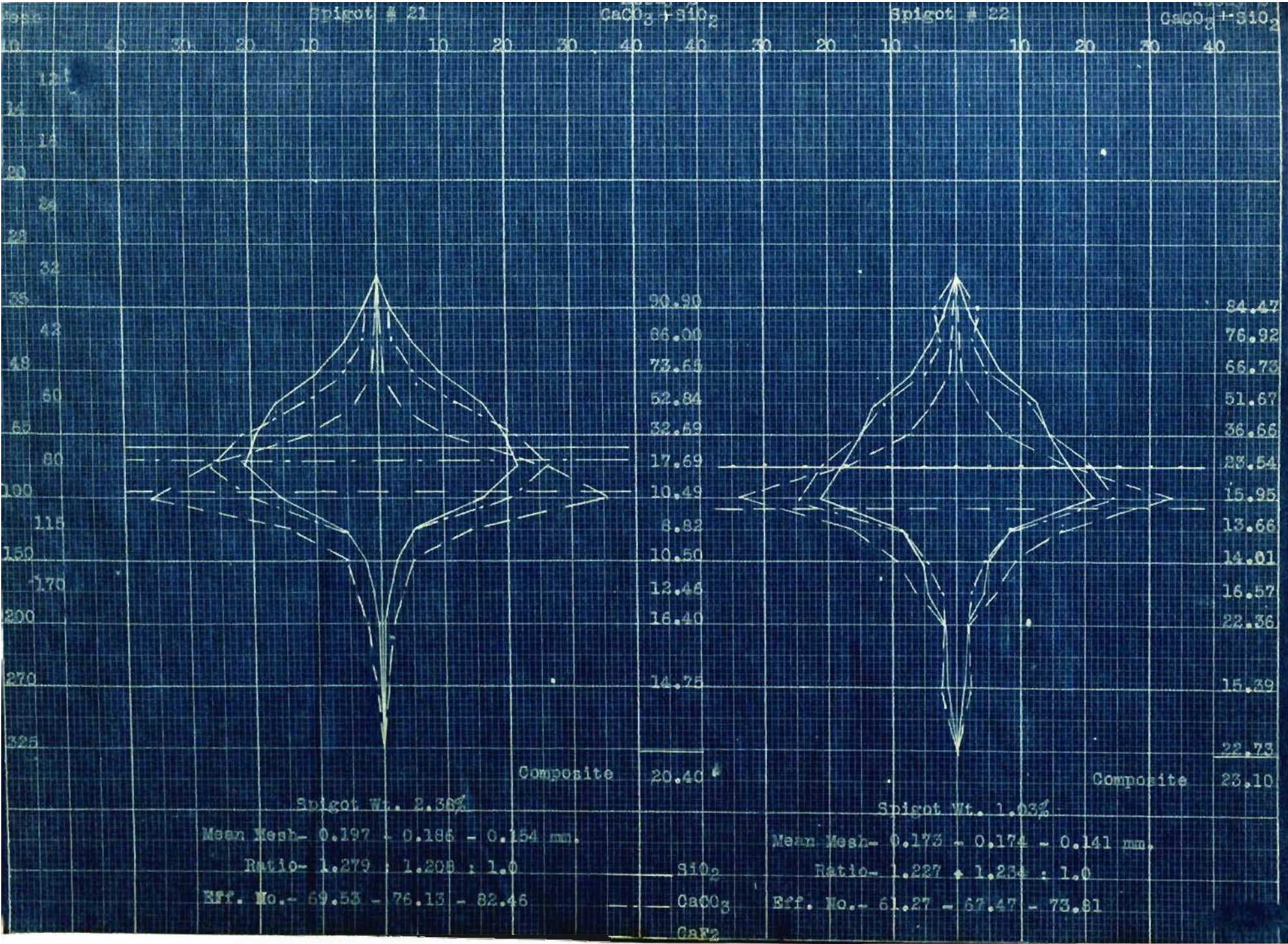


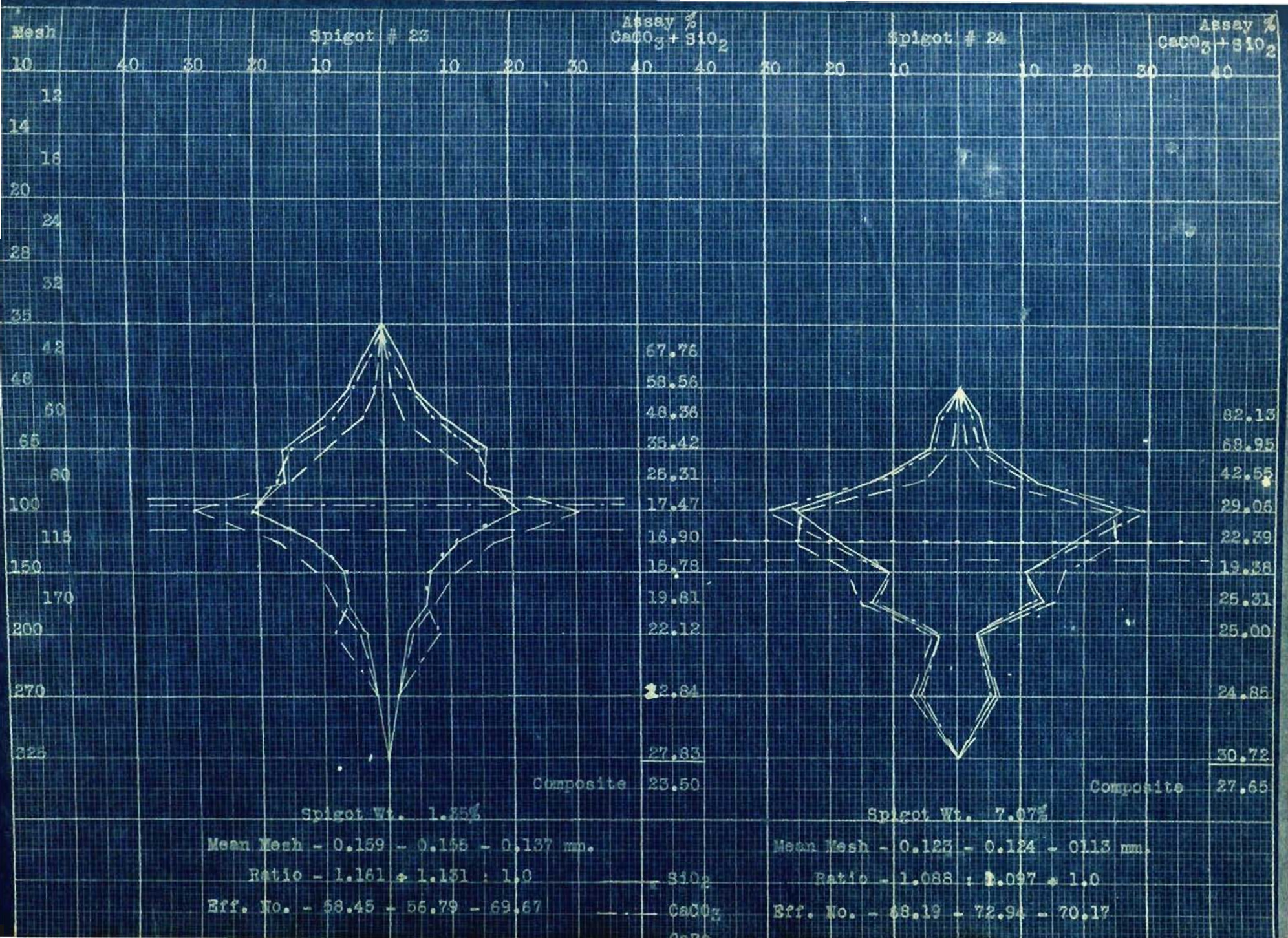

Mesh
Spigot # 13
$CaCO_3 + SiO_2$
Spigot # 14
$CaCO_3 + SiO_2$
10 40 30 20 10 10 20 30 40 40 30 20 10 10 20 30 40
12
14
16
20
24
28
32
35
42
48
60
65
80
100
115
150
170
200
270
325
99.66
96.87
90.57
65.07
31.76
11.65
5.46
3.61
3.35
3.49
4.65
5.47
7.05
Composite 14.62
92.77
92.61
74.15
42.20
18.07
5.86
3.54
2.53
3.00
3.36
4.02
6.85
Composite 12.63
SiO_2
$CaCO_3$
CaF_2
Smigot Wt. 1.62%
Mean Mesh - 0.593 - 0.503 - 0.3[illegible] mm.
Ratio - 1.524 : 1.290 : 1.0
Eff. No. - 66.72 - 68.70 - 75.76
Spigot Wt. 2.00%
Mean Mesh - 0.950 - 0.472 - 0.375 mm.
Ratio - 1.467 : 1.259 : 1.0
Eff. No. - 70.34 - 74.84 - 77.36


Mesh
Spigot # 15
Assay %
$CaCO_3 + SiO_2$
Spigot # 16
Assay %
$CaCO_3 + SiO_2$
10 40 30 20 10 10 20 30 40 40 30 20 10 10 20 30 40
12
14
16
20
24
28
32
35
42
48
60
65
80
100
115
150
170
200
220
325
95.08
96.94
91.54
72.16
36.16
14.44
7.51
5.74
5.23
5.68
9.15
8.22
12.05
20.49
28.47
97.34
98.59
92.18
69.63
28.73
11.58
6.02
4.06
3.70
4.29
5.08
7.57
10.85
27.06
32.79
Composite 15.37
Composite 14.78
SiO_2
$CaCO_3$
CaF_2
Spigot Wt. 3.94%
Mean Mesh — 0.449 — 0.390 — 0.308 mm.
Ratio — 1.458 : 1.266 : 1.0
Eff. No. — 58.04 — 62.36 — 68.63
Spigot Wt. 0.94%
Mean Mesh — 0.495 — 0.412 — 0.331 mm.
Ratio. — 1.495 : 1.245 : 1.0
Eff. No. — 66.79 — 68.85 — 72.43


Mesh
Spigot # 17
Assay % $CaCO_3 + SiO_2$
10 40 30 20 10 10 20 30 40 40 30 20 10
12
14
16
20
24
28
32
35
42
48
60
65
80
100
115
150
170
200
270
325
96.51
98.32
93.69
76.86
33.41
11.24
5.00
3.24
3.47
3.25
4.14
7.65
13.97
Composite 13.23
SiO_2
$CaCO_3$
CaF_2
Spigot Wt. 1.11%
Mean Mesh — 0.493 — 0.428 — 0.358 mm.
Ratio — 1.469 : 1.262 : 1.0
Eff. No. — 72.01 — 74.75 — 79.81
Spigot # 18
Assay % $CaCO_3 + SiO_2$
10 10 20 30 40
97.72
97.15
88.71
54.11
24.64
12.20
7.52
3.19
7.40
8.07
9.83
23.43
16.62
19.77
27.90
Composite 15.37
Spigot Wt. 4.66%
Mean Mesh — 0.573 — 0.344 — 0.269 mm.
Ratio — 1.387 : 1.279 : 1.0
Eff. No. — 49.08 — 53.18 — 64.72


Mesh
Spigot # 19
$CaCO_3 + SiO_2$
Spigot # 20
$CaCO_3 + SiO_2$
10 40 30 20 10 10 20 30 40 40 30 20 10 10 20 30 40
12
14
16
20
24
28
32
35
42
48
60
65
80
100
115
150
170
200
270
325
95.46
79.64
50.30
27.42
15.76
11.75
10.24
9.53
9.65
12.12
12.63
22.49
24.59
38.55
16.85
52.03
75.29
52.02
31.10
19.21
13.26
9.36
6.67
6.94
8.15
12.16
17.22
Composite 16.26
Spigot Wt. 15.40%
Composite
Mean Mesh—0.273—0.260—0.217 mm.
Ratio—1.258 : 1.198 : 1.0
Eff. No.—50.16—57.98—64.72
Spigot Wt. 19.40%
Mean Mesh—0.242—0.230—0.191 mm.
Ratio.—1.276 : 1.204 : 1.0
Eff. No.—66.05—70.58—74.11
SiO_2
$CaCO_3$
CaF_2


Spigot # 21
$CaCO_3 + SiO_2$
Spigot # 22
$CaCO_3 + SiO_2$
90.90
86.00
73.66
52.84
32.59
17.69
10.49
8.82
10.50
12.46
16.40
14.75
20.40
84.47
76.92
66.73
51.67
36.66
23.54
15.95
13.66
14.01
16.57
22.36
15.39
22.73
23.10
Composite
Composite
Spigot Wt. 2.36%
Mean Mesh- 0.197 - 0.186 - 0.154 mm.
Ratio- 1.279 : 1.208 : 1.0
Eff. No.- 69.53 - 76.13 - 82.46
Spigot Wt. 1.03%
Mean Mesh- 0.173 - 0.174 - 0.141 mm.
Ratio- 1.227 : 1.234 : 1.0
Eff. No.- 61.27 - 67.47 - 73.81
SiO_2
$CaCO_3$
CaF_2


Mesh
Spigot # 23
Assay % $CaCO_3 + SiO_2$
10 40 30 20 10 10 20 30 40 40
13
14
16
20
24
28
32
35
42
48
60
65
80
100
115
150
170
200
270
325
67.76
58.56
48.36
35.42
25.31
17.47
16.90
15.78
19.81
22.12
12.84
27.83
Composite 23.50
Spigot Wt. 1.85%
Mean Mesh - 0.159 - 0.145 - 0.137 mm.
Ratio - 1.161 : 1.131 : 1.0
Eff. No. - 58.45 - 56.79 - 69.67
Spigot # 24
Assay % $CaCO_3 + SiO_2$
50 20 10 10 20 30 40
82.13
68.95
42.55
29.06
22.39
19.38
25.31
25.00
24.85
30.72
Composite 27.65
Spigot Wt. 7.07%
Mean Mesh - 0.123 - 0.124 - 0113 mm.
Ratio - 1.088 : 1.097 : 1.0
Eff. No. - 68.19 - 72.94 - 70.17
SiO_2
$CaCO_3$

Spigot # 25

Assay % $CaCO_3 + SiO_2$

| Mesh | | |

Mesh

Spigot Overflow

$CaCO_3 + SiO_2$

10 40 30 20 10 10 20 30 40

12

14

16

20

24

28

32

35

42

48

60

65

80

100

115

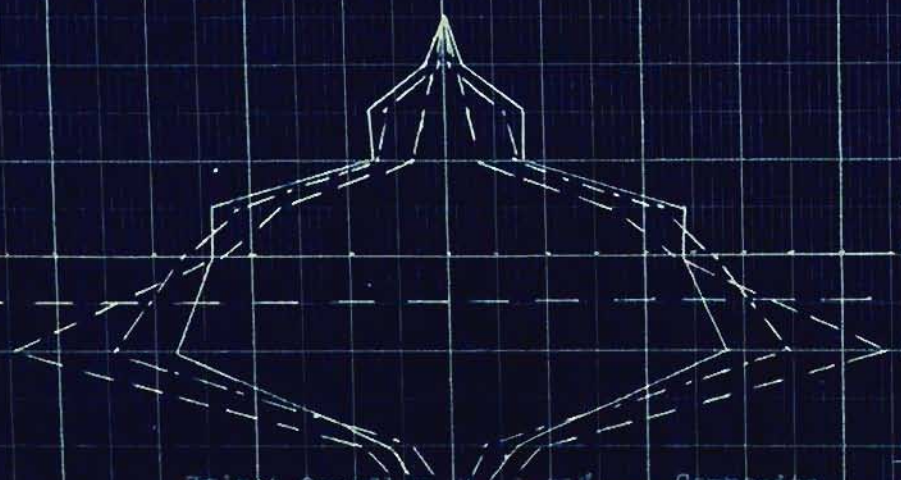
150

170

200

270

325



67.42

72.46

60.18

51.03

43.85

32.35

33.01

42.48

Spigot Overflow Wt. 1.81% Composite

Mean Mesh — 0.072 — 0.076 — 0.068 mm.

Ratio — 1.147 : 1.118 : 1.0

Eff. No. — 83.06 — 86.94 — 80.47

——— SiO_2

— — — $CaCO_3$

——— CaF_2

The mean mesh of the silica, calcite and fluorite, respectively, is shown by the horizontal lines across the figure; the symbols assigned formerly are used. The assay of the "silica plus calcite" is tabulated at the side of each diagram. Below each diagram the percentage weight of the spigot discharge, mean mesh, the ratio of the mean mesh of the silica and calcite, respectively, to fluorite, and the efficiency number are given.

Each diagram gives an idea of what kind of work each respective spigot performed. For example, we notice in Spigots 1 and 2 that the diagram is very wide; this shows close sizing. In fact the efficiency numbers are very high. This is as would be expected because the feed was sized through 10 mesh. As we proceed to Spigot 3 the geometrical figure of calcite falls between that of silica and fluorite. This arrangement of the various materials in an ore in the order of their specific gravity is sought in classification.

In the diagrams of the first two spigots the curves for the respective minerals nearly coincide, that is, the mean meshes are about the same. This is another way of saying that the hindered-settling ratios are small. The efficiency numbers are higher than found in any of the other spigots because the feed to the first spigot was sized through 10 mesh. When Spigot 3 or 4 is reached the hindered-settling ratios are slipped down in the order of the increasing specific gravity minerals. In the first two or three spigots the sizing is excellent, but the settling ratios do not seem attractive. The poor ratios in the first two spigots are as expected: The coarse

gangue, which would have given a high ratio was removed by the limiting screen—10 mesh. However, the ratios do not cause concern because sizing has been achieved. After the third spigot the ratios appear in greater favor. Toward the latter end of the series the ratios and efficiency numbers—particularly the ratios—become less satisfactory. This marks the limits in classification exacted by increasing fineness. The overflow has a better appearance than the latter spigots. This is because no account is taken of the amount which passed through the 325 mesh sieve. Therefore, the ratio and efficiency numbers of the overflow are too high and must not be considered in making comparisons.

It is axiomatic that any classified product may be trued up by further classification. The extent is shown in Figure 5-A and by the data given in Table VI; this is further brought out by the comparative values of the mean mesh, etc. at the bottom of Table VII. The truing-up was done by feeding the material of Spigot 5 to a one-spigot classifier, and making a spigot and an overflow product. The efficiency numbers were increased about ten points.

The mean mesh, ratio, and efficiency number for silica, calcite and fluorite in each of the 27 spigots are shown in Table VII.

The limit of fineness in hydraulic classification is shown by the ratios in Table VII to occur at about the twenty-third spigot. The average mean mesh of this spigot is very near the 100 mesh sieve. A decided decrease in the ratio of the average size of silica and calcite to fluorite takes place in this spigot and throughout the rest of the series. However, efficiency numbers do not show a similar decrease.

Figure 5-A. Reclassification of Spigot 5.

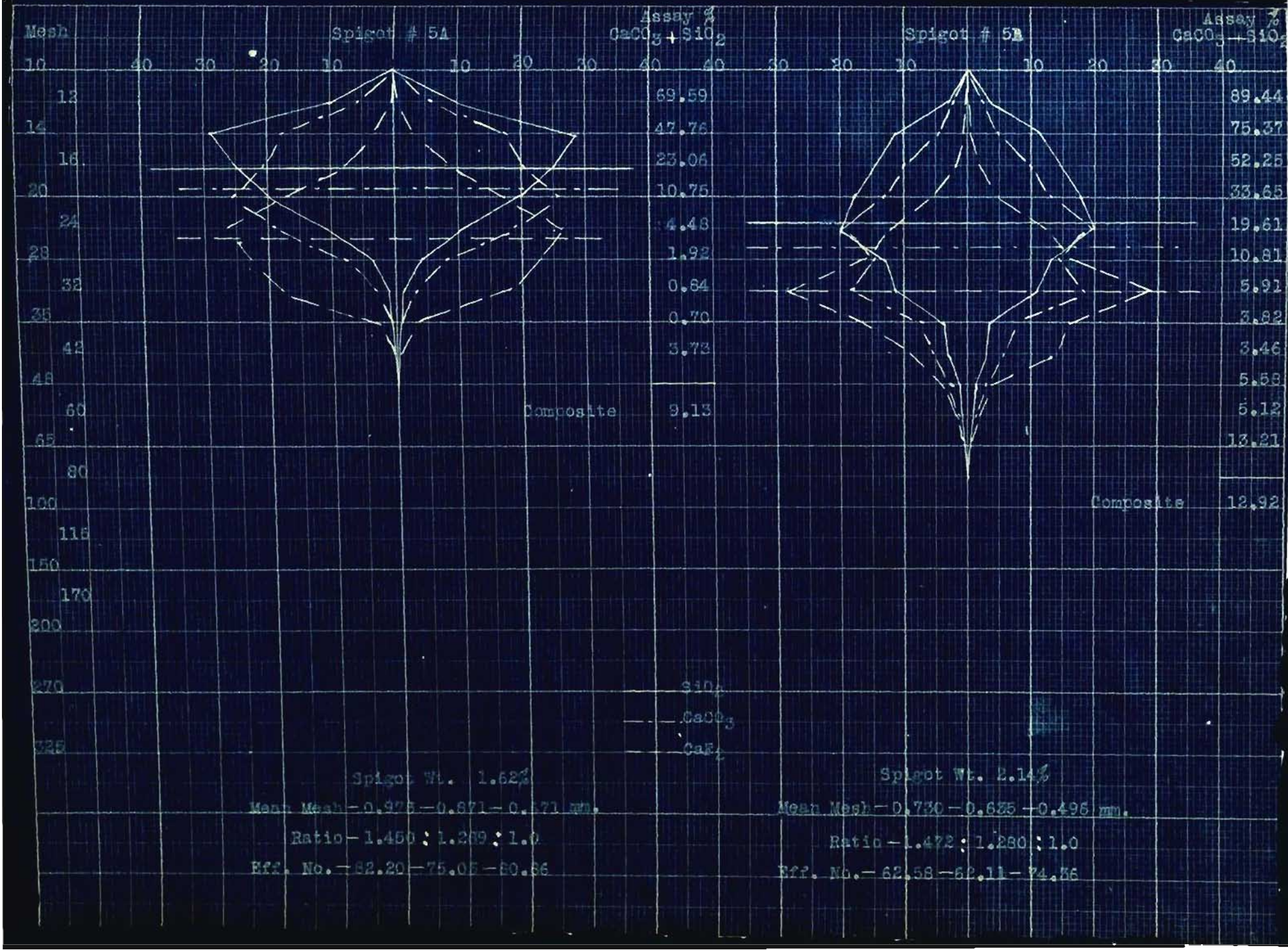

Mesh
Spigot # 5A
Assay % $CaCO_3 + SiO_2$
10 40 30 20 10 10 20 30 40 40
12 69.59
14
16 47.76
20 23.06
24 10.75
28 4.48
32 1.92
35 0.84
42 0.70
48 3.73
60 Composite 9.13
65
80
100
115
150
170
200
270
325
SiO_2
$CaCO_3$
CaF_2
Spigot Wt. 1.62%
Mean Mesh – 0.976 – 0.671 – 0.471 mm.
Ratio – 1.450 : 1.269 : 1.0
Eff. No. – 82.20 – 75.05 – 80.86
Spigot # 5B
Assay % $CaCO_3 - SiO_2$
40 30 20 10 10 20 30 40
89.44
75.37
52.25
33.65
19.61
10.81
5.91
3.82
3.46
5.58
5.12
13.21
Composite 12.92
Spigot Wt. 2.14%
Mean Mesh – 0.730 – 0.685 – 0.496 mm.
Ratio – 1.472 : 1.280 : 1.0
Eff. No. – 62.58 – 62.11 – 74.56

Table VI. Screen Analyses of Reclassified Spigot Product.

Spigot 5-A - 49.52 Per cent Weight of Spigot 5.

M e s h	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	1.18	61.67	9.71	7.92	5.73	30.41	0.39
-12 + 14	5.16	42.22	29.06	5.54	17.51	52.24	2.97
-14 + 16	9.64	19.64	25.26	3.42	20.20	76.94	8.16
-16 + 20	17.71	8.39	19.82	2.36	25.60	89.25	17.39
-20 + 24	25.09	3.24	10.85	1.24	19.06	95.52	26.38
-24 + 28	21.35	1.32	3.76	.60	7.85	98.08	23.04
-28 + 32	16.43	.51	1.12	.33	3.32	99.16	17.93
-32 + 35	2.80	.53	.20	.17	.29	99.30	3.06
-35 + 42	.64	2.61	.22	1.12	.44	96.27	.68
	100.00	7.50	100.00	1.63	100.00	90.87	100.00

Table VI (Continued). Screen Analyses of Reclassified Spigot Product.

Spigot 5-B - 50.48 Per cent Weight of Spigot 5.

Mesh	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
-10 + 12	0.43	79.44	3.07	10.00	2.42	10.56	0.05
-12 + 14	1.79	70.73	11.37	4.64	4.67	24.63	.51
-14 + 16	3.45	47.08	14.58	5.17	10.02	47.75	1.89
-16 + 20	6.57	30.14	17.78	3.51	12.95	66.35	5.01
-20 + 24	13.11	16.96	19.96	2.65	19.51	80.39	12.10
-24 + 28	15.74	9.15	12.93	1.66	14.68	89.19	16.12
-28 + 32	26.54	4.68	11.15	1.23	18.33	94.09	28.67
-32 + 35	14.34	2.92	3.76	.90	7.25	96.18	15.84
-35 + 42	12.41	2.76	3.08	.76	5.30	96.48	13.75
-42 + 48	3.52	4.14	1.31	1.44	2.85	94.42	3.82
-48 + 60	1.59	3.46	.49	1.66	1.48	94.88	1.73
-60 + 65	.51	11.32	.52	1.89	.54	86.79	.51
	100.00	11.14	100.00	1.78	100.00	87.08	100.00

Table VII. Summary of Mean Mesh, Ratios, and Efficiency Numbers.

Spigot Number	Mean Mesh in Millimeters			Ratio			Efficiency Number			Average
	SiO_2	$CaCO_3$	CaF_2	SiO_2	$CaCO_3$	CaF_2	SiO_2	$CaCO_3$	CaF_2	
1	1.113	1.156	1.087	1.023	1.063	1	84.78	92.74	81.42	86.31
2	1.053	1.044	0.955	1.103	1.093	1	76.98	73.69	73.00	74.56
3	1.041	0.950	0.808	1.288	1.176	1	80.64	82.12	72.21	78.32
4	0.944	0.857	0.708	1.333	1.210	1	65.32	71.32	66.36	67.67
5	0.816	0.705	0.560	1.457	1.259	1	61.63	61.28	67.72	63.54
6	0.858	0.679	0.562	1.526	1.208	1	71.85	64.86	79.34	72.02
7	0.788	0.646	0.515	1.530	1.254	1	63.07	60.80	72.28	65.38
8	0.747	0.635	0.493	1.515	1.288	1	65.70	64.48	77.49	69.22
9	0.796	0.651	0.507	1.570	1.284	1	71.48	74.26	82.66	76.12
10	0.722	0.632	0.465	1.553	1.359	1	65.87	67.33	71.36	68.19
11	0.699	0.581	0.453	1.543	1.283	1	65.93	69.28	77.20	70.80
12	0.677	0.565	0.439	1.542	1.287	1	73.00	75.43	85.04	77.82
13	0.599	0.503	0.393	1.524	1.280	1	66.72	69.70	75.76	70.73
14	0.550	0.472	0.375	1.467	1.259	1	70.34	74.54	77.38	74.09
15	0.449	0.390	0.308	1.458	1.266	1	58.04	62.36	68.63	63.01
16	0.495	0.412	0.331	1.495	1.245	1	66.79	68.35	72.43	69.19
17	0.493	0.428	0.338	1.459	1.262	1	72.01	74.75	79.81	75.52
18	0.373	0.344	0.269	1.387	1.279	1	49.08	53.18	64.72	55.66
19	0.273	0.260	0.217	1.258	1.198	1	50.16	57.98	64.72	57.62
20	0.242	0.230	0.191	1.267	1.204	1	66.05	70.58	74.11	70.25
21	0.197	0.186	0.154	1.279	1.208	1	69.53	76.13	82.46	76.04
22	0.173	0.174	0.141	1.227	1.234	1	61.27	67.47	73.81	67.52
23	0.159	0.155	0.137	1.161	1.131	1	58.45	56.79	69.67	61.64
24	0.123	0.124	0.113	1.088	1.097	1	68.19	72.94	70.17	70.43
25	0.123	0.124	0.112	1.098	1.107	1	64.23	69.03	69.32	67.53
26	0.111	0.113	0.103	1.078	1.097	1	65.29	66.22	65.75	65.75
Overflow	0.078	0.076	0.068	1.147	1.118	1	83.06	86.94	88.47	86.16
5-A	0.973	0.871	0.671	1.450	1.289	1	82.20	75.03	80.86	79.36
5-B	0.730	0.635	0.496	1.472	1.280	1	62.58	62.11	74.36	66.35

These observations are in accord with well known principles, to wit: (1) When material is very fine the specific gravity does not have much influence upon the falling velocity, and (2) when a mineral is very fine the falling velocity varies as to the square of the diameter, whereas when it is coarser the velocity varies directly as the diameter. To show how this idea is brought out in experimental results the last eight spigots of this series are divided into groups of four each and the "Average ratio" and the "Average efficiency number" for each group is given in Table VII-A below.

Table VII-A. Comparison of Degree of Classification of the Intermediate Size and the Finest Size.

Spigot Number	Mean Mesh of Group Between Sieves	Average Ratio of			Average of the Average Efficiency Numbers for the Group
		SiO_2	$CaCO_3$	CaF_2	
19 20 21 22	-60 to 80 mesh	1.258	1.211	1.0	67.85
23 24 25 26	-100 to 150 mesh	1.106	1.108	1.0	66.34

The above table shows how the ratios decrease in the latter spigots; the break is at about 100 mesh. But sizing, which is shown by the efficiency numbers continues without a similar variation. Thus the limits of classification of the ore at hand are closely drawn.

Screen Analyses of Spigot Products.

In the screen analyses of the original ore a gradual increase in silica from 65 mesh on down is shown and the same occurs just a few meshes higher in the screen analyses of each spigot. This can be explained better after the feed to each spigot is known; the explanation follows:

In Table VIII the assay per cent of silica, calcite and fluorite in the feed to each spigot is compared to the same in the discharge from each spigot. The calculation of the feed to the successive spigots is very tedious but the information gained has made it worth while. It shows that quartz is carried toward the discharge end of the classifier and justifies the high quartz content of the last spigot. For instance, the silica content of the feed to the first spigot is only 17.93, whereas in the feed to the last spigot it is 36.17 per cent.

In general the silica content in the feed shows an increase from pocket to pocket and the same may be said for the discharge. But, when the ratio of the silica in the feed to the silica in the discharge is considered it will be seen how hydraulic classification failed in the finer sizes.

The gradual building up of silica in the composite analysis of the feed to each pocket as shown is the natural result of classification. The same thing occurs for each mesh of the spigot, as it is followed from spigot to spigot. A specific citation of this is made in Table VIII.

Table VIII. Feed Per Pocket and Discharge Per Spigot.

Pocket or Spigot Number	Assay Per cent SiO_2		Ratio	Assay Per cent $CaCO_3$		Ratio	Assay Per cent CaF_2		Ratio
	Feed to Pocket	Discharge from Spigot		Feed to Pocket	Discharge from Spigot		Feed to Pocket	Discharge from Spigot	
1	17.93	1.61	0.09	1.88	0.59	0.31	80.19	97.80	1.22
2	18.07	3.54	.20	1.89	1.04	0.55	80.04	95.42	1.19
3	18.27	5.63	.31	1.90	1.38	.73	79.83	92.99	1.16
4	18.62	7.04	.38	1.92	2.17	1.13	79.46	90.79	1.14
5	18.96	10.53	.56	1.91	1.97	1.03	79.13	87.50	1.11
6	19.37	12.08	.62	1.91	2.01	1.05	78.72	85.91	1.09
7	19.43	11.10	.57	1.91	1.73	.91	78.66	87.17	1.11
8	19.54	10.33	.53	1.91	1.89	.99	78.55	87.78	1.12
9	19.62	12.01	.61	1.91	1.74	.91	78.47	86.25	1.10
10	19.66	11.55	.59	1.91	2.01	1.05	78.44	86.44	1.10
11	19.69	10.92	.55	1.91	1.69	.88	78.40	87.39	1.11
12	19.72	12.25	.62	1.91	1.70	.89	78.37	86.05	1.10
13	19.86	11.94	.60	1.91	1.68	.88	78.23	86.38	1.10
14	20.03	10.84	.54	1.92	1.52	.79	78.05	87.64	1.12
15	20.26	13.64	.67	1.93	1.73	.90	77.81	84.63	1.09
16	20.61	13.10	.64	1.94	1.68	.87	77.45	85.22	1.10
17	20.70	11.47	.55	1.94	1.76	.91	77.36	86.77	1.12
18	20.87	13.40	.64	1.95	1.97	1.01	77.18	84.63	1.10
19	21.36	15.07	.71	1.95	1.78	.91	76.69	83.15	1.08
20	23.20	14.38	.62	1.99	1.88	.94	74.81	83.74	1.12
21	28.32	18.65	.66	2.05	1.75	.85	69.63	79.60	1.14
22	29.05	21.15	.73	2.08	1.95	.94	68.87	76.90	1.11
23	29.30	21.56	.74	2.08	1.94	.93	68.62	76.50	1.11
24	29.69	25.56	.86	2.09	2.09	1.00	68.22	72.35	1.06
25	31.03	24.11	.78	2.09	1.88	.90	66.88	74.01	1.11
26	36.17	35.80	.99	2.24	2.19	.98	61.57	62.01	1.01
Overflow	39.78			2.70			57.52		
Composite		17.93			1.88			80.19	

In Table IX Spigots 6 and 20 have been taken as representative of coarse and fine material. On the 28 to 32 mesh in Spigot 6 the feed is 20.98 per cent silica with a discharge of 2.07 per cent silica. On the same mesh in Spigot 20 the feed is 58.57 per cent silica and the discharge is 49.02 per cent silica, which gives a very good illustration of how the lighter material of any one mesh is passed on down from spigot to spigot, constantly building up in grade. Of course the reverse holds true for the heaviest mineral—fluorite. Incidentally it may be said that the calcite, being of intermediate density of small percentage, does not show much variation.

Table IX. Comparison of Spigot 6 and Spigot 20 in Respect to Screen Analyses of Feed to Pocket and Discharge from Spigot.

Screen Size	Spigot 6			Spigot 20		
	Assay Per cent SiO_2		Ratio	Assay Per cent SiO_2		Ratio
	Feed to Pocket	Discharge from Spigot		Feed to Pocket	Discharge from Spigot	
-10 + 12	87.63	84.66	0.97			
-12 + 14	79.52	77.06	.97			
-14 + 16	71.00	53.11	.75			
-16 + 20	50.43	28.69	.57			
-20 + 24	36.17	12.30	.34			
-24 + 28	26.56	4.62	.17			
-28 + 32	20.98	2.07	.10	58.57	49.02	0.84
-32 + 35	17.47	1.12	.06	71.11	70.00	.98
-35 + 42	15.88	1.35	.09	49.36	47.49	.96
-42 + 48	14.69	2.02	.14	29.89	27.83	.93
-48 + 60	14.42	4.26	.30	22.37	16.71	.75
-60 + 65	14.23	5.56	.39	18.66	11.47	.62
-65 + 80	16.10	7.41	.46	18.95	8.32	.44
-80 + 100				20.15	5.80	.29
-100 + 115				21.99	6.21	.28
-115 + 150				21.40	7.31	.34
-150 + 170				30.69	10.61	.35
-170 + 200				27.50	15.37	.56
Composite	19.37	12.08	.62	23.20	14.38	.62

Tabling.

Hydraulic classification prepares the ore for further benefication on tables. It is therefore in order to take up a discussion of the results obtained by tabling.

Three spigot products were tabled, namely, Spigots 15, 20 and 25. These three spigots were chosen in order to prove that small grain-size material could be handled advantageously on tables as well as larger material which is, in common practice, amenable.

Spigot 15 was tabled on an 18 by 42 inch Wilfley laboratory table. Ten 4-inch cuts were made, seven along the side and three on the end. They are numbered from the mechanism end toward the concentrate end. Each cut was given a chemical analysis. The results appear in Table X.

Cuts 1, 2 and 3 can be considered as tailings, thereby discarding 55 per cent of the silica content and only losing 11 per cent of the fluorspar. Or, if considered from the assay viewpoint the assay value of fluorspar has been raised from 84 to 90 per cent and the silica lowered from 11 to 5 per cent.

Table XI shows the results of tabling Spigot 20 on a quarter-size Butchart table, Model 6. The assays were made by the sink-and-float method.

The cuts were each ten inches in length, being numbered from the mechanism end to the concentrate end of the table. "A" and "B" denote one-half of a cut, or five inches.

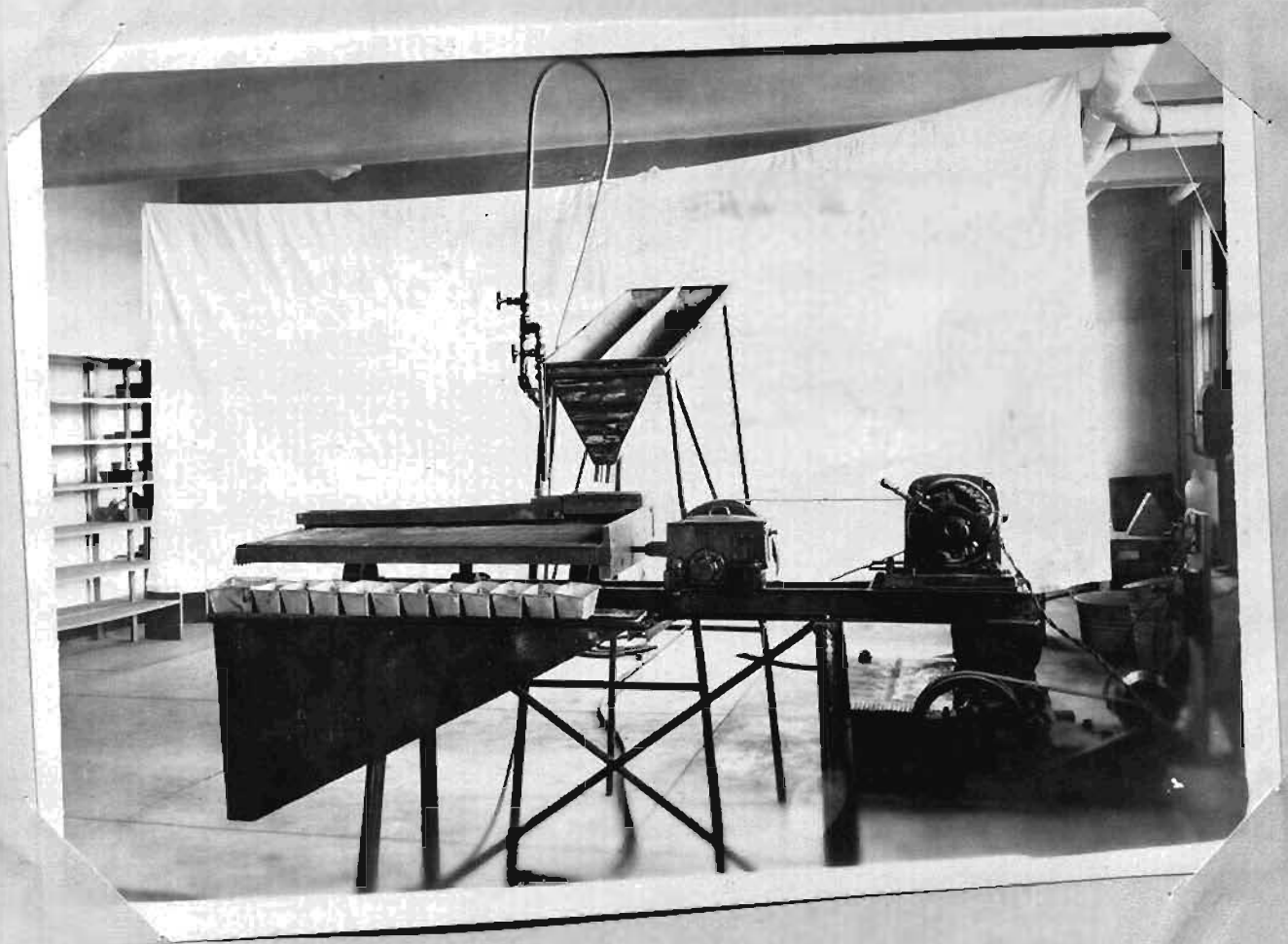


Figure 6. Wilfley Laboratory Table.

Table X. Laboratory Table Test, Spigot 15 - Mean Mesh 0.35 mm. (42 mesh).

Number of Cuts	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2	Assay Percent R_2O_3	Distribution of the R_2O_3
1	0.61	52.81	2.98	8.82	2.08	29.84	0.22	8.53	2.30
2	6.19	50.10	28.68	7.22	17.26	35.77	2.63	6.91	18.89
3	10.53	24.11	23.48	4.41	17.93	68.35	8.53	3.13	14.55
4	15.26	10.40	14.68	2.66	15.67	85.04	15.39	1.90	12.80
5	15.97	6.50	9.60	1.70	10.48	90.26	17.09	1.54	10.86
6	13.05	5.52	6.66	1.34	6.76	91.77	14.20	1.37	7.89
7	9.23	4.80	4.10	1.21	4.31	92.32	10.10	1.67	6.81
8	11.76	4.25	4.62	1.38	6.27	92.86	12.95	1.51	7.84
9	13.78	3.52	4.48	2.05	10.91	92.38	15.10	2.05	12.48
10	3.62	2.16	0.72	5.96	8.33	88.39	3.79	3.49	5.58
	100.00	10.81	100.00	2.59	100.00	84.33	100.00	2.26	100.00

Table XI. Laboratory Table Test, Spigot 20 - Mean Mesh 0.21 mm. (65 mesh).

Number of Cut	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
1	0.15	86.55	0.84	11.11	0.73	2.34	---
2	.54	91.52	3.19	7.84	1.85	.64	---
3	2.29	89.56	13.25	9.11	9.11	1.33	0.04
4-A	2.54	87.14	14.29	8.00	8.87	4.86	.15
4-B	3.71	71.86	17.21	8.70	14.09	19.44	.88
5-A	6.10	40.05	15.78	6.69	17.82	53.26	3.95
5-B O' flow	1.69	64.48	7.04	6.55	4.83	28.97	.60
5-B Spigot	5.93	7.68	2.94	2.79	7.21	89.54	6.45
6-A	10.99	9.99	7.09	2.14	10.27	87.87	11.74
6-B	16.11	6.69	6.95	1.35	9.49	91.96	18.02
7-A	14.70	4.56	4.33	.99	6.35	94.45	16.89
7-B	17.38	4.15	4.66	.81	6.15	95.04	20.09
8	1.90	4.15	.51	.78	.65	95.07	2.20
9	15.97	1.85	1.91	.37	2.58	97.78	18.99
	100.00	15.48	100.00	2.29	100.00	82.22	100.00

NOTE: The Cut 10 was omitted from calculations. It was 3.35 per cent by weight and contained material heavier than fluorspar; it assayed as follows: 0.64 per cent SiO_2; 0.11 per cent $CaCO_3$; 74.27 per cent CaF_2, and 24.98 per cent undetermined iron, barium, etc.

Cut 5-B was classified in a laboratory classifier making an "overflow" and "spigot" to simulate commercial work where middlings are returned. Assuming the spigot of 5-B and all the following cuts as concentrate, and the overflow of 5-B and all above to be tailings, the grades of the concentrate and tailing were calculated; the results are:

Product	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2
Tailing	17.02	65.14	71.60	7.71	57.30	27.15	5.62
Concentrate	82.98	5.30	28.40	1.18	42.70	93.52	94.38
Composite	100.00	15.48	100.00	2.29	100.00	82.22	100.00

The rejection of silica and calcite is very good when compared with the small amount of fluorite lost.

Spigot 25 was too small in amount to treat on a quarter-size table. Hence it was treated the same as Spigot 15, that is, on a minature table. Twelve 4-inch cuts were made, ten along the side and two on the end. The results of the chemical analysis for each cut are given in Table XII.

A comparison of the assay of the cuts shows beneficiation, although the material was very fine and the table was of minature size.

The following tabulation compares the two methods of assaying, that is, chemical versus heavy liquid.

Table XII. Laboratory Table Test, Spigot 25 - Mean Mesh 0.12 mm. (115 mesh).

Number of Cut	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2	Assay Percent R_2O_3	Distribution of the R_2O_3
1	0.82	59.87	1.92	10.11	2.78	22.30	0.27	7.72	1.97
2	6.36	61.70	15.31	6.90	14.72	23.90	2.23	7.50	14.90
3	9.93	42.78	16.57	4.57	15.22	47.41	6.90	5.24	16.26
4	10.53	31.60	12.98	3.52	12.43	61.76	9.54	3.12	10.26
5	17.86	26.82	18.68	2.88	17.25	67.32	17.63	2.98	16.63
6	9.77	25.09	9.56	2.71	8.88	69.73	9.99	2.47	7.54
7	16.44	20.05	12.86	2.23	12.30	75.39	18.18	2.33	11.97
8	10.26	15.94	6.38	1.94	6.68	79.84	12.02	2.28	7.31
9	6.91	12.34	3.33	1.68	3.90	84.04	8.52	1.94	4.19
10	4.60	8.17	1.46	1.26	1.95	88.67	5.98	1.90	2.73
11	5.81	3.78	.86	1.57	3.06	91.80	7.82	2.85	5.17
12	.71	3.45	.09	3.50	.83	88.22	.92	4.83	1.07
	100.00	25.64	100.00	2.98	100.00	68.18	100.00	3.20	100.00

Table	Spigot	Percent SiO_2	Percent $CaCO_3$	Percent CaF_2	Percent R_2O_3	Method of Analysis
4	15	13.64	1.73	84.63	---	Heavy liquid
9	15	10.81	2.59	84.33	2.26	Chemical
4	25	24.11	1.88	74.01	---	Heavy liquid
11	25	25.64	2.98	68.18	3.20	Chemical

In the above notation we have a very good comparison of the heavy liquid method of analysis to that of the chemical. The error is due almost entirely to mixed crystals. The fact that the heavy liquid method is not as accurate as the chemical method of analysis was known before this work was begun, but, it is a much more rapid method and is accurate when used only for purposes of comparison. Since comparison of the various spigot products to one another was the important feature of this work, it was adapted. Approximately 2000 determinations were made by the heavy liquid method, which would have required more time by the chemical method than would have been available. When greater accuracy was desired chemical assays were made; these totaled about two hundred.

As shown, tabling classified products, even though these products may be extremely fine, improves the grade of the ore, but the percentage recovery of the acid grade is very small. Therefore, classification and tabling must be considered as conditioners of the ore preparatory to a final treatment when acid spar is sought.

Decrepitation.

Decrepitation was tried as the final process for material coarser than 35 mesh. Spigot Products 1, 2, and 3 were tabled and the concentrates were decrepitated. The decrepitation was made on an electric hot plate with a cover to confine the decrepitating charge. The plate itself was at an estimated temperature of 700° C. The ore was stirred frequently while being decrepitated. About twenty minutes was required to conclude the decrepitation.

After the ore cooled it was screened on a 35 mesh screen. The minus 35 mesh material was called "first concentrate." The plus size was again decrepitated and screened. The minus 35 mesh grains from the second decrepitation was called "second concentrate."

The ore before decrepitation assayed as follows:

$CaCO_3$ -- 1.16 per cent

SiO_2 -- 2.44 per cent

CaF_2 -- 96.40 per cent.

The percentage recovery and grade of products made is shown in Table XIII. The silica content of the concentrates is very low. All the assays were made by the heavy liquid method.

Table XIII. Grade of Fluorspar Concentrates Made by Decrepitation.

Product	Weight Percent	Percent SiO_2	Percent $CaCO_3$	Percent CaF_2
First concentrate	77.48	0.40	0.78	98.32
Second concentrate	6.31	.50	.98	97.97
Tailings	16.21	11.00	7.08	79.12

The probable cause for the necessity of "re-decrepitation" was the imperfection of the furnace used.

Flotation.

It is quite apparent that before any of the above methods can be adopted it will be necessary—at least in part—to recover fluorite from the fine material. It was with this in mind that all attention was turned toward flotation.

A 100-pound sample of log-washed gravel fluorspar was taken. It showed by examination that the mineral broke free at 100 mesh. The ore assayed as follows:

$CaCO_3$	--	1.73 per cent
SiO_2	--	27.90 per cent
CaF_2	--	67.94 per cent
R_2O_3	--	2.43 per cent.

A Case flotation machine, manufactured by the Denver Fire Clay Company, Denver, Colorado, was used in this part of the investigation. This machine was operated at an impeller speed of 1350 r. p. m. and with a charge of 500 grams of ore and 2000 cc. of water.

The ore was crushed to 100 mesh in a disc pulverizer. It was then placed in the flotation cell with distilled water and agitated until thoroughly mixed before the first charge of flotation reagents was added; then again agitated a few minutes before any froth was drawn off. A second charge of reagents was added after approximately five minutes and a third charge after another period of

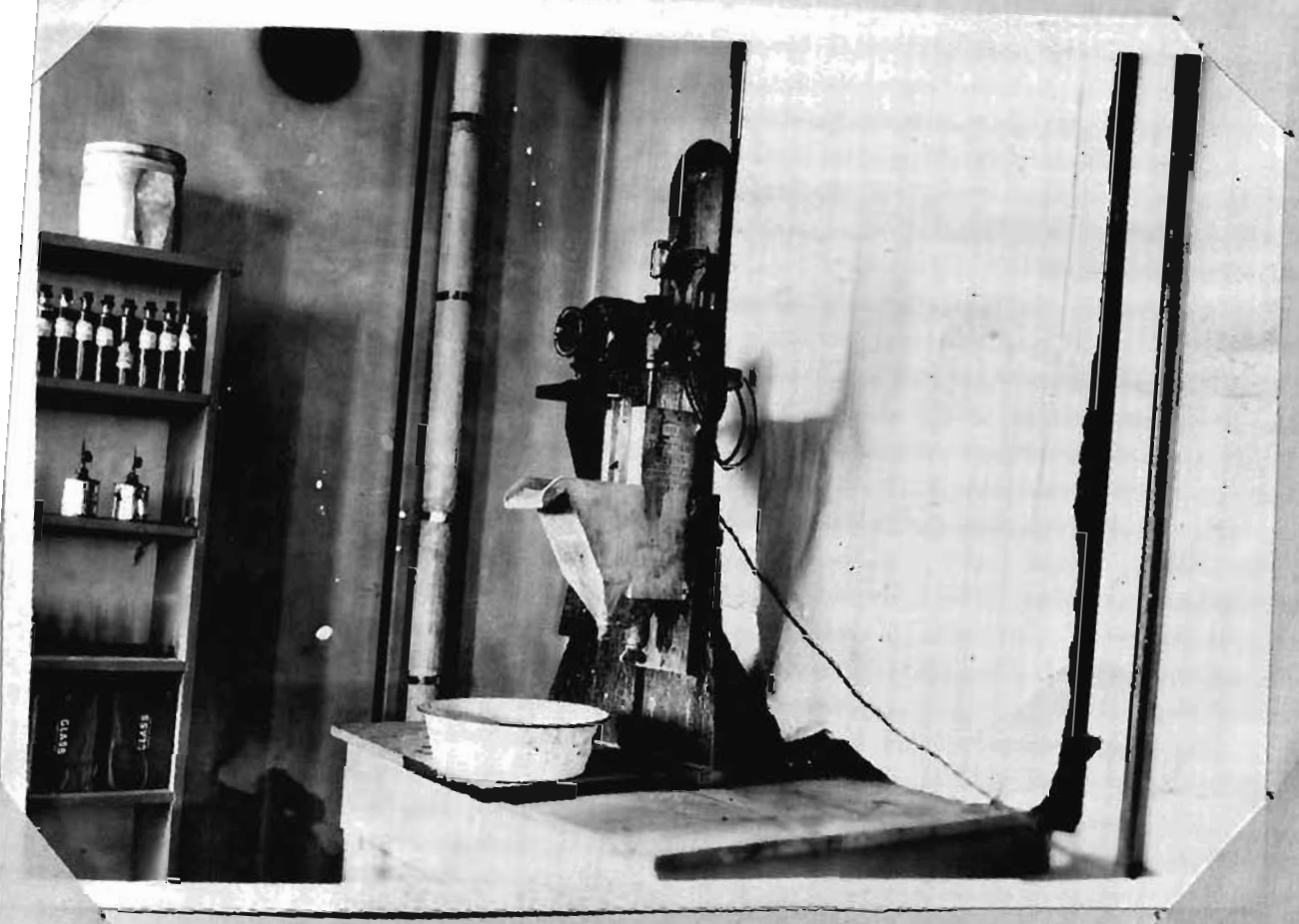


Figure 7. Case Flotation Machine.

similar length. The period between charges was dependent on the character of the froth and the amount of material carried over the lip of the machine. Thus, by adding the reagents in this manner the reagent concentration was kept fairly constant, although it was necessary to add water to the cell from time to time in order to maintain the pulp level necessary for operation.

Oleic acid, heavy crude oil, pine oil, sodium oleiate, sodium silicate and sodium carbonate were used as reagents. The sodium oleiate was diluted to a five per cent solution and the sodium silicate and carbonate to a ten per cent solution. After many runs, using various reagents, the above named reagents gave the best results by using the quantities as indicated in Table XIV:

Table XIV. Flotation Reagents Per Charge.

Charge	Rougher Cell Reagents						Cleaner Cell Reagents	
	Oleic Acid drops	Sodium Oleiate drops	Heavy Crude drops	Sodium Silicate drops	Pine Oil S. Dis. drops	Sodium Carbonate drops	Sodium Silicate drops	Sodium Carbonate drops
1	4	3	1	10	1	10	15	10
2	2	2	1	4	1	4		
3	1	1	-	4	-	4		

The assay of the products using the flotation reagents listed in the above table are given in Table XIV-A following:

Table XIV-A. Assay Results of Flotation Products Using Reagents in Table XIV.

Product	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2	Assay Percent R_2O_3	Distribution of the R_2O_3
Concentrate	52.61	2.76	5.20	0.49	14.89	96.03	74.36	0.72	15.59
Middling	24.90	38.85	34.68	2.05	29.49	54.53	19.99	4.57	45.83
Tailing	22.49	74.58	60.12	4.28	55.62	17.08	5.65	4.06	37.58
Composite	100.00	27.90	100.00	1.73	100.00	67.94	100.00	2.43	100.00

The following test is identical with the preceding experiment except that the charge was ground in an Abbe pebble mill.

Table XV. Flotation Reagents Per Charge.

Charge	Rougher Cell Reagents						Cleaner Cell Reagents	
	Oleic Acid drops	Sodium Oleiate drops	Heavy Crude drops	Sodium Silicate drops	Pine Oil S. Dist. drops	Sodium Carbonate drops	Sodium Silicate drops	Sodium Carbonate drops
1	4	3	1	10	1	10	15	10
2	2	2	1	4	1	4		
3	1	1	-	4	-	4		

The assay of the products using the flotation reagents listed in Table XV are given in Table XV-A following:

Table XV-A. Assay Results of Flotation Products Using Reagents in Table XV.

Product	Weight Percent	Assay Percent SiO_2	Distribution of the SiO_2	Assay Percent $CaCO_3$	Distribution of the $CaCO_3$	Assay Percent CaF_2	Distribution of the CaF_2	Assay Percent R_2O_3	Distribution of the R_2O_3
Concentrate	56.07	0.60	1.21	0.57	18.47	98.23	81.07	0.60	13.83
Middling	17.76	33.24	21.16	1.93	19.81	61.69	16.12	3.14	22.92
Tailing	26.17	82.75	77.63	4.08	61.72	7.29	2.81	5.88	63.25
Composite	100.00	27.90	100.00	1.73	100.00	67.94	100.00	2.43	100.00

Since the only difference between the two preceeding experiments was in the method of grinding, it is seen that grinding in an Abbe mill produces a pulp more adaptable for flotation.

The latter test resulted in the production of an "acid grade" fluorspar with a good recovery (81.07 per cent) of the fluorite in the concentrate. The amount of spar left in the tailings was very low (2.81 per cent) and it is probable that the middlings produced in the cleaning treatment could be re-treated with results similar to those obtained on the original feed.

Laboratory flotation tests have indicated that it is possible to produce an acid grade spar by this method. Good recoveries have been made but before this method can be applied successfully on a commercial basis a number of factors must be investigated. One of the most important is the type of water to be used in the mill operation. Hard water may consume an excessive amount of reagent, particularly oleic acid and sodium oleiate, and may require softening before using.

SUMMARY.

The treatment of the fines in fluorspar ores has always been a problem due to the inability of making a marketable product. In the past the fines have largely gone to waste. The purpose of this investigation was primarily to find some method of milling the fine sized waste into a fancy grade of concentrate—acid spar. The scope was further extended to make acid spar from the ordinary run of ores.

Tailings from the sludge pond of the Haffaw Mill, Mexico, Kentucky, constituted the principal part of the material used in this investigation. These tailings contain approximately 80 per cent fluorite, but in spite of this high mineral content are valueless, being too fine to be graded up and sold for "gravel spar." Practically the only market open for fines is for the grade containing 98 per cent calcium fluoride, known as acid spar. Therefore, an attempt was made to produce a concentrate of this grade. This grade of ore commands a considerable higher price than the gravel grade.

The density ratio of the fluorspar to gangue is very small, making the ore difficult to treat by ordinary gravity methods. Detailed work in classification was undertaken to study principles as well as the amenability of the ore.

A small glass laboratory classifier was used to determine the size of fluorite and silica particles having equal-falling velocities. From the data thus obtained and from the screen analysis of the ore, the theoretical number of spigots and the quantity that each spigot should let down was calculated. Tests on a larger scale were then made in which a Richards hydraulic classifier was used.

In order to compare the products of classification in a comprehensive manner, a unique method of plotting the results was devised. Two expressions: "Mean Mesh" and "Efficiency Number" were used to reduce the efficiency of each spigot to numerical terms.

A number of table tests made on classified feeds indicated that it is possible to table classified material of a size much finer than formerly supposed. Although the possibility of beneficiating the ore markedly by tabling classified feeds was proven, it is doubtful if a great amount of acid spar can be made by this method except in the treatment of very high grade ores crushed not finer than 20 mesh—0.83 mm.

Decrepitation was also tried as a means of producing an acid spar. Material coarser than 35 mesh could be treated by this method and about 75 per cent of the fluorite graded up to acid grade. Although acid spar was produced about 25 per cent of the fluorite remained in the tailings. Such a method would be of *no* value in treating material finer than 35 mesh.

Excellent results were obtained in the laboratory in the flotation of fluorspar. Acid grade spar was made from a sample containing 28 per cent silica. The recovery of spar was also good; 81 per cent of the spar being contained in the concentrate, 2.8 per cent in the tailings, and the balance in the middlings. It is probable that successful re-treatment of the middlings can also be accomplished.

While it is likely that a number of difficulties will have to be overcome before flotation can be applied commercially, it is believed that the method has many possibilities, especially in the treatment of fine ores that are complex and require fine grinding.

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